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Review Article

Effects of Air Pollution on Human Health and Prevention Strategies: A Brief Review

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ABSTRACT

Indoor and outdoor air pollution in enclosed and open environments is one of the most critical environmental factors affecting human health and can be associated with a wide range of respiratory, cardiovascular, gastrointestinal, dermatological, and other health disorders. Bioaerosols, as biological components of air pollution, are of particular significance, especially in indoor environments, healthcare facilities, schools, and occupational settings. This review aimed to evaluate the available evidence on health outcomes associated with exposure to indoor and outdoor air pollutants, with an emphasis on bioaerosols, as well as to identify individual and managerial strategies for preventing or mitigating these outcomes. In this review, articles published between 2000 and 2025 were retrieved using relevant keywords across Cochrane, Google Scholar, Embase, Medline, Scopus, ProQuest, and Iranian databases, including Iranmedex, Irandoc, and SID. Out of 1,550 identified articles, 30 were included in the study. The findings indicated that exposure to air pollutants and bioaerosols is linked to respiratory and cardiovascular disorders, as well as certain dermatological, gastrointestinal, and other adverse health outcomes. Source reduction or elimination and minimizing the duration and intensity of exposure are the most effective preventive strategies. The use of appropriate respiratory protective equipment, adherence to personal hygiene, proper ventilation and indoor air quality control, and the adoption of a healthy lifestyle, such as adequate nutrition, regular physical activity, sufficient sleep, and smoking cessation, can effectively reduce the adverse impacts of air pollution exposure. Effective prevention of the health consequences of air pollution requires an integrated combination of individual, environmental, and managerial interventions, with a primary focus on source control and exposure reduction.

Keywords: Air Pollution; Bioaerosols; Human Health; Indoor and Outdoor Air Pollutants; Prevention

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Introduction

Air pollution is recognized as the single largest environmental risk to human health and one of the most critical global public health challenges [1]. According to the State of Global Air 2025 report, air pollution accounted for 7.9 million premature deaths worldwide. Of these, 4.9 million deaths were attributable to ambient fine particulate matter ($PM_{2.5}$) exposure, 2.8 million to household air pollution, approximately 470,000 to long-term exposure to ground-level ozone, and 626,000 Alzheimer's disease-related deaths were linked to air pollution. Individuals are continuously exposed to airborne physical, chemical, and microbial agents both inside and outside occupational settings. Throughout daily life, humans encounter a broad spectrum of physical, chemical, and biological pollutants across diverse indoor and outdoor environments [2]. Indoor and outdoor air quality is governed by emission sources, meteorological conditions, building characteristics (such as geographical location and occupant density), human activities, and the performance of ventilation systems [3]. Consequently, identifying pollutants, assessing exposure levels, and investigating their health impacts are paramount for safeguarding human health.

Exposure to ambient and indoor air pollutants elicits a wide range of adverse health outcomes. Particulate matter particularly $PM_{2.5}$ ozone, and nitrogen dioxide can trigger oxidative stress and the generation of reactive oxygen species (ROS). Furthermore, these pollutants are closely associated with the onset and exacerbation of respiratory and cardiovascular diseases, allergic responses, and various chronic conditions, thereby escalating mortality risks and posing severe threats to human well-being [4].

In addition to chemical pollutants, airborne biological agents represent critical constituents of air pollution. This issue assumes heightened significance in enclosed environments, where individuals spend a substantial proportion of their time. Outdoor environments serve as the primary reservoir for microbial diversity within indoor spaces [5]. Bioaerosols a class of airborne biological pollutants posing substantial health hazards comprise bacteria (such as *Streptococcus pneumoniae*), fungi (*Histoplasma* spp.), viruses (e.g., rhinoviruses), spores, cellular fragments, and other biogenic particulates. Individuals inhale bioaerosols alongside other airborne contaminants during outdoor and indoor activities. These agents can be released into the atmosphere from human, animal, and plant sources, as well as soil, dust, moisture reservoirs, and ventilation systems. Under baseline conditions, fungal spore concentrations typically range from 10^3 to 10^4 spores/m^3 of air. The concentration and taxonomic composition of bioaerosols are modulated by several determinants, including ambient environmental conditions, relative humidity, temperature, occupant density, anthropogenic activities, and ventilation system specifications. In other words, bioaerosols thrive optimally in environments characterized by elevated humidity and moderate temperatures conditions predominantly observed in crowded indoor spaces [6].

Exposure to certain bioaerosols can be associated with respiratory infections, allergic reactions, toxicities, airway irritation, and other adverse health outcomes [7]. Legionnaires' disease is a form of pneumonia caused by the inhalation of *Legionella pneumophila* bacteria (measuring 1-5μm) disseminated through heating, ventilation, and air conditioning (HVAC) systems. Bioaerosols exist in diverse forms, including solid particulates, liquid droplets, and microbial volatile organic compounds (mVOCs) [8]. In enclosed environments, the exposure of susceptible individuals and patients to airborne microorganisms increases the likelihood of acquiring infectious diseases a hazard that remains substantially underrecognized [9]. Natural sources of bioaerosols in indoor air include coughing and sneezing; furthermore, the risk of infectious transmission escalates through the recirculation of air via ventilation systems and close contact between infected and susceptible individuals via inhalation of pathogenic bioaerosols [10, 11].

Vulnerable populations such as children, older adults, and individuals with underlying medical conditions exhibit heightened susceptibility to the adverse effects of air pollution (RCPCH, 2022). Children and school-aged students warrant particular attention due to their developing respiratory systems, elevated physical activity rates, and extended stays within educational facilities, rendering them exceptionally susceptible to ambient and indoor environmental pollutants [12]. Therefore, evaluating air quality in educational environments and identifying prevailing pollutants are essential for preventing deleterious health consequences. Indoor bioaerosol concentrations in settings such as elementary school classrooms across several countries, including Iran, frequently exceed World Health Organization (WHO) guideline thresholds. Clinical and epidemiological manifestations attributed to these pollutants encompass elevated mortality rates, an increased incidence of respiratory illnesses, elevated risk of gastric cancer, and lower respiratory tract infections in populations spanning from neonates to children aged 15 years [13, 14]. The assessment of air pollution and bioaerosols is conducted via diverse physical, chemical, and microbiological approaches. Measuring particulate matter and gaseous pollutant concentrations, active ambient air sampling, enumerating and identifying microorganisms, and utilizing culture-based, microscopic, and molecular assays represent standard methodological paradigms for monitoring air quality and bioaerosol dynamics. Selecting an appropriate assessment strategy depends on the pollutant

taxonomy, study objectives, environmental matrix characteristics, and analytical sensitivity requirements [15-17] Nonetheless, methodological heterogeneity in sampling protocols, identification pipelines, and reporting frameworks poses substantial challenges for cross-study comparative analyses.

Overall, published literature addressing specific preventive interventions against individual-level pollutant exposure remains scarce. Complete prevention of bioaerosol inhalation in children is practically unfeasible due to their intense physical activity and heightened physiological vulnerability; however, targeted preventive interventions can substantially mitigate overall exposure burdens in pediatric cohorts. Preventing and mitigating the adverse consequences of air pollution necessitate a multi-tiered framework spanning individual- and managerial-level interventions. Evidence indicates that avoiding exposure constitutes the most definitive strategy for preventing the adverse effects of bioaerosols.

Managerial and engineering controls including source emission containment, enhanced and optimized mechanical ventilation, regular maintenance of HVAC and cooling systems, indoor humidity regulation, rigorous environmental cleaning, and occupant density reduction—serve as critical interventions for mitigating indoor air contamination. At the individual level, minimizing proximity to pollution sources and correctly employing personal respiratory protective equipment (RPE) under high-risk conditions can effectively lower exposure doses. The efficacy of these interventions varies according to pollutant types, microenvironmental parameters, and exposure scenarios, underscoring the critical need to synthesize empirical evidence to guide optimal preventive decision-making.

Despite extensive research on air pollution and bioaerosols, current evidence regarding analytical methods, clinical endpoints, and mitigation strategies remains fragmented. Methodological disparities and fluctuating environmental conditions impede cross-study comparisons and standardized interpretations. Furthermore, data specifically reflecting the epidemiological and environmental conditions in Iran across the combined axes of air pollution, bioaerosols, and health impacts have rarely been synthesized systematically. A structured synthesis of the literature is therefore vital to clarify methodological approaches, establish attributable health outcomes, and determine effective mitigation measures.

This study was designed to address the central research question: "What does the current evidence indicate regarding health outcomes associated with indoor and outdoor air pollutant exposure, specifically bioaerosols, and how effective are individual and administrative mitigation strategies in preventing or reducing these outcomes?" Accordingly, this review systematically synthesizes the available evidence on air pollution and bioaerosols, examining the health consequences of exposure to indoor and outdoor airborne contaminants with an emphasis on bioaerosols, evaluating monitoring and diagnostic methodologies, and detailing individual and managerial interventions, with a contextual focus on findings from Iran.

Methods

To identify relevant studies, a comprehensive literature search covering the period from 2000 to 2026 was conducted across international and national electronic databases. International databases comprised the Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, PubMed, Embase, Scopus, ProQuest, ScienceDirect, SpringerLink, and Google Scholar. Iranian national literature was indexed through IranMedex, Irandoc, SID (Scientific Information Database), and Magiran.

The search strategy integrated relevant Persian keywords and English Medical Subject Headings (MeSH) combined with Boolean operators (AND, OR). Terms encompassed:

Exposure & bioaerosol descriptors: "bioaerosol", "airborne bacteria", "airborne fungi", "airborne microorganisms"

Indoor and outdoor health contexts: "indoor air quality", "sick building syndrome", "indoor respiratory illnesses", "outdoor bioaerosols", "ambient bioaerosols", "ambient respiratory diseases"

Clinical endpoints: "respiratory", "dermatological", "cardiovascular", "carcinogenic", "gastrointestinal"

Methodological and control strategies: "air sampling", "detection", "identification", "quantification", "monitoring", "air filtration", "personal protective equipment", "mitigation", "interventions", and "Iran"

Search algorithms were customized to the specific syntax and indexing rules of each respective platform. The publication window was restricted to 2000–2026 in accordance with eligibility parameters, and literature tracking was managed based on publication date and complete text availability.

To enhance reproducibility and methodological rigor, explicit eligibility criteria were established *a priori*.

Inclusion Criteria

Original, peer-reviewed research articles published in recognized national or international journals;
Studies published between 2000 and 2026;

Investigations conducted in indoor and/or ambient outdoor environments;

Studies examining bioaerosols or airborne microorganisms, or evaluating sampling, identification, enumeration, and quantification methods;
Methodologies employing physical, microbiological,

culture-dependent, microscopic, or molecular analytical techniques for bioaerosol evaluation;
Availability of the complete full-text manuscript;
Articles published in English or Persian.

Exclusion Criteria

Duplicate citations;
Studies lacking direct relevance to bioaerosols or co-occurring chemical airborne contaminants;
Manuscripts without full-text accessibility;
Secondary or non-original literature, including letters to the editor, editorials, conference abstracts, case reports, theses/dissertations, and non-peer-reviewed technical reports;
Studies published outside the specified time window (pre-2000 or post-2026);
Studies with incomplete or poorly reported methodologies regarding air sampling, taxonomic identification, microbial counting, or physical measurement.

Following deduplication, two investigators independently screened all retrieved records by title and abstract. Potentially eligible studies were subsequently subjected to full-text assessment against the inclusion criteria. Screenings were conducted independently in duplicate. Any discrepancies between the reviewers were resolved through consensus discussion or, where necessary, adjudication by a third independent reviewer.

The identification, screening, eligibility, and inclusion phases were conducted and reported in strict compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement [18] . Figure 1 presents the PRISMA

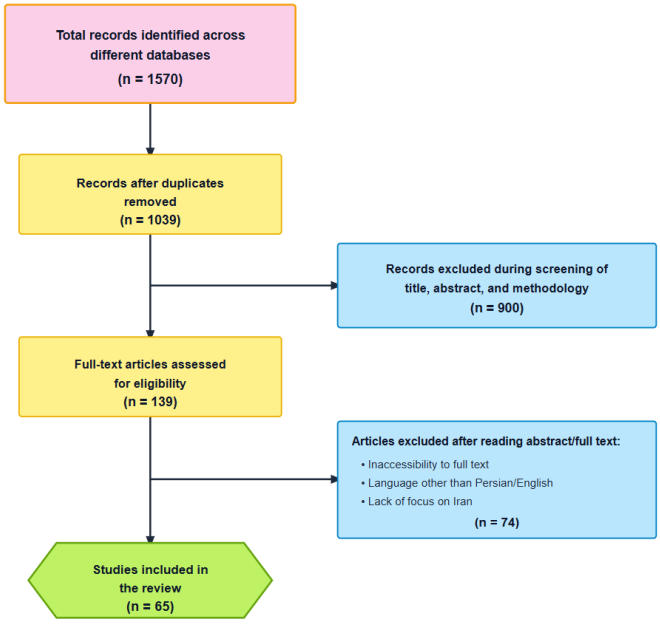

Figure 1: PRISMA flow diagram for the screening and inclusion process of selected studies.

Table 1: Air Sampling Methods for Assessing Bioaerosol Concentrations in Indoor and Outdoor Air [19]

No.	Method	Description
1	Sedimentation (Passive Sampling; Indoor Air)	Sterile culture plates containing an appropriate growth medium are exposed to the ambient air for a specified period. Airborne microorganisms settle onto the culture medium by gravity. The plates are subsequently incubated, and the number of microbial colonies is counted after 24–48 h.
2	Centrifugal Sampling	A predetermined volume of air is introduced into a chamber containing a solid culture medium, where airborne microorganisms are collected through centrifugal forces. Following incubation, the number of microbial colonies is determined.
3	Filtration	A predetermined volume of air is drawn through a 0.3-µm membrane filter. The filter is then placed on an appropriate culture medium and incubated at 37°C. The number of microbial colonies is counted after 24–48 h.
4	Electrostatic Precipitation	This method is based on the displacement and collection of charged particles within an electric field and is used for separating and collecting airborne microorganisms, particularly in industrial applications.
5	Liquid Impingement (Air Sampling into Liquid Medium)	A predetermined volume of air is aspirated into the sampling device and introduced into a sterile liquid medium. An aliquot of the collected liquid is subsequently cultured, and the number of microbial colonies is determined based on the microorganisms present per unit volume of sampled air.

flow diagram detailing study selection. Table 1 summarizes the air sampling techniques utilized for bioaerosol concentration assessment across indoor and outdoor environments [19] .

Methodological note: No single bioaerosol collection device can achieve complete, 100% quantitative capture and recovery of viable airborne microorganisms, primarily due to mechanical stress, impaction shock, desiccation, and microbial inactivation during the sampling process.

Results

Table 2 outlines the impacts of indoor and ambient microbial pollutants across various physiological systems.

Table 3 outlines the studies conducted on bioaerosols in Iran, providing local evidence regarding assessment methods, bioaerosol exposure stages, health outcomes, and the efficacy of preventive strategies.

Step 1:Assessment and Control of Indoor and Ambient Air Pollution

The findings of the reviewed studies indicate that air quality assessment constitutes the primary foundational stage for characterizing exposure levels and establishing pollution control priorities. Tabulated findings reveal marked heterogeneity across studies regarding assessment methodologies, targeted pollutants, and investigated environments. While certain investigations focused on particulate matter specifically $PM_{2.5}$, PM_{10},

Table 2: Effects of microbial and other indoor and ambient air pollutants on physiological systems

No.	Target System / Organ	Epidemiological and Experimental Findings
1	Respiratory System & Bioaerosol Allergens	• Suresh et al. (2000): Demonstrated that air pollution–induced imbalances between antioxidar defenses and nitric oxide levels disrupt pulmonary function and precipitate respiratory disease [20]. • Paulus (2015): Reported that tobacco smoke exposure aggravates dyspnea symptoms and leads to impaired lung function [21]. • Hartiala et al. (2026): Highlighted that bioaerosols—encompassing viable microorganisms, metabolic byproducts, cellular debris, pollens, and fungal spores—and elevated concentration of specific airborne pathogens, allergens, mycotoxins, and endotoxins trigger substantial adverse clinical outcomes in sensitized and atopic cohorts (Hartiala, Elenius et al. 2026).
2	Cardiovascular & Hematological Systems	• Harte (2014): Showed that smoking cessation normalizes resting heart rate via favorable recovery of myocardial function. Nutritional status was also identified as a critical determinan in modulating host defense against airborne diseases [22]. • Padma et al. (2014): Demonstrated the efficacy of the DASH diet (rich in potassium and magnesium, low in sodium, with abundant vegetables, fruits, whole grains, lean meats, fish, an nuts) in blood pressure control [23]. • Sarmasti et al. (2019): Identified documented histories of hematological disorders in 9.1% (2 of 22) of occupationally exposed fuel station workers across Tehran's 22 municipal districts [24].
3	Gastrointestinal System	• Kaplan et al. (2009): Documented a significantly elevated risk of acute appendicitis among adults exposed to ambient air pollution compared to unexposed cohorts [25]. • Ananthakrishnan et al. (2011): Established significant positive correlations between hospitalization rates for inflammatory bowel conditions and atmospheric gaseous pollutants, verifying an association between air pollution and gastrointestinal morbidity [26]. • Hao et al. (2026): Conducted a meta-analysis demonstrating that acute and chronic exposure to particulate matter ($PM_{2.5}$, PM_{10}) and gaseous criteria pollutants (NO_2, SO_2, CO, O_3) is significantly associated with gastrointestinal pathologies (Hao, Zhang et al. 2026).
4	Integumentary System (Skin)	• Key pollutants compromising cutaneous integrity include ultraviolet (UV) radiation, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), particulate matter, and nitrogen oxides (NO_x) • Kampa and Castanas (2008): Reported that UV radiation impairs skin tissue in a wavelength dependent manner, accelerating extrinsic cutaneous aging (photoaging) [27]. • Burke and Wei (2009): Confirmed that ambient air pollutants synergistically exacerbate UV induced cutaneous photodamage [28]. • Norval and McKenzie (2011): Estimated that a 1% increase in effective UV exposure correlates with a 2–3% rise in skin cancer incidence [29]. • Valacchi et al. (2012): Linked air pollution exposure to the pathogenesis of cutaneous malignancies, notably malignant melanoma, basal cell carcinoma (BCC), and squamous cell carcinoma (SCC) [30].
5	Carcinogenesis & Systemic Toxicities	• Manye et al. (2020): Calculated the 90th percentile Incremental Lifetime Cancer Risk (ILCR associated with peak concentrations of total suspended particles (TSP), PM_{10}, $PM_{2.5}$, PM_1, nickel (pulmonary carcinogen), arsenic (pulmonary carcinogen), mercury (nephrotoxic), and cadmium (osteotoxic/carcinogenic) at 6.0, 5.1, 2.3, 0.86, 0.0037, 0.26, 0.0027, 0.0020, and 0.0055 per million, respectively [31].

Table 3: Studies of Bioaerosols in Indoor and Outdoor Air in Iran

Province	Key Study Findings & Contextual Insights
East Azerbaijan	• Kazemi et al. (2013): Identified *Penicillium* as the predominant airborne fungal spore isolated from ambient air in Tabriz. Atmospheric fungal spores represent a notable air pollution fraction capable of inducing severe human health complications, particularly respiratory illnesses.[۳۲] • Khodabandehlou (2016): Reported *Aspergillus*, *Penicillium*, and *Cladosporium* as the primary fungal genera recovered from hospital ward air in Miandoab during winter. Recommended the design and implementation of technical-managerial interventions and high-efficiency ventilation systems to reduce exposure risks for patients and visitors [33].
Isfahan	• Nourmoradi (2011): Documented the lowest bioaerosol concentrations within operating theaters of Isfahan University of Medical Sciences hospitals. Higher indoor bacterial densities relative to outdoor baselines were linked to patient census, occupational movement, inadequate air exchange, and suboptimal disinfection, highlighting the need for stringent environmental controls in immunocompromised wards[34]. • Taheri and Golbabaei (2011): Reported mean airborne total aerosol and bioaerosol concentrations of 2.4 ± 1.4 mg/m^3 and 430 ± 332 CFU/m^3, respectively, in rural home-based carpet weaving workshops. Given the dual residential-occupational setting and the presence of diverse opportunistic pathogens, these microenvironments present substantial health risks to residents [35]. • Mirhoseini et al. (2015): Observed bacterial load ranges spanning 75 to 1,194 CFU/m^3 across hospital wards, corroborating considerable indoor bioaerosol contamination and potential nosocomial transmission in healthcare facilities [36]. • Golshahi et al. (2016): Observed a significant incidence of left ventricular systolic dysfunction among industrial steel plant workers occupationally exposed to airborne particulate emissions [37]. • Mirhoseini et al. (2020): Recorded mean airborne bacterial and fungal densities of 516 and 176 CFU/m^3, respectively, using Andersen cascade impactors. The predominant fungal taxa identified constitute major airborne allergens capable of impairing respiratory health among primary school students in classroom environments [38].
Alborz	• Ghanizadeh and Godini (2018): Established that complex co-exposures to chemical and microbiological airborne contaminants in hospital indoor environments directly undermine patient, healthcare worker, and visitor health, correlating with an array of nosocomial endpoints [39]. • Talabi et al. (2019): Identified a non-significant correlation between bacterial and fungal counts in the operating rooms of Shariati Hospital in Karaj. Gram-positive bacteria, *Penicillium*, and *Aspergillus* exhibited the highest survival resistance under adverse conditions, demonstrating the necessity of standardized surface and atmospheric decontamination protocols [40].
Ilam	• Najafi et al. (2014): Reported *Bacillus* as the dominant bacterial genus isolated from ambient air during spring dust storms in western Iran. Findings emphasize desert dust events as major drivers of ambient particulate and bioaerosol exposure across regional populations [41].
Bushehr	• Farrokhi et al. (2015): Identified house dust mites as the most prevalent indoor aeroallergen among cohorts diagnosed with asthma and allergic rhinitis. Elevated regional temperature and ambient relative humidity were identified as primary determinants modifying skin prick test (SPT) reactivity profiles [42]. • Chehregani et al. (2004): Demonstrated that urban air pollution microscopically alters pollen morphology, protein composition, and allergenic potency, rendering mature pollen grains substantially more allergenic than immature equivalents [43].
Tehran	• Naddafi et al. (2009): Monitored airborne bacterial density within the Children's Medical Center Hospital using Quick Take 30 samplers, finding that recovered taxa predominantly comprised human physiological microflora originating from the dermis, respiratory tract, and gastrointestinal mucosa [44]. • Naddafi et al. (2011): Documented significantly higher bacterial densities within underground metro stations (Imam Khomeini and Sadegheyeh) compared to ambient outdoor air, highlighting the need for routine microbiological surveillance and active HVAC management in high-density mass transit hubs [44] • Abdollahi et al. (2012): Identified *Micrococcus* spp. and *Cladosporium* spp. as the most prevalent airborne bacterial and fungal isolates on the campus grounds of Imam Khomeini Hospital. High-efficiency filtration and ultraviolet germicidal irradiation (UVGI) were advocated to lower airborne biocontaminant loads [46]. • Azimi et al. (2013): Found *Aspergillus* to be the predominant airborne fungal genus across hospital inpatient wards. Elevated spore levels were attributed to operational lapses (e.g., frequent door cycling between sterile and non-sterile areas) and inadequate HVAC filtration allowing unconditioned outdoor air [47]. • Hosseini et al. (2013): Confirmed elevated indoor bacterial loads in metro platforms relative to outdoor environments. Airborne fungal concentrations showed positive correlations with commuter density ($r = 0.68, p < 0.05$) and relative humidity ($r = 0.43, p < 0.05$) [48]. • Shams-Ghahfarokhi et al. (2014): Identified *Aspergillus* as the prevailing genus in ambient outdoor air, concluding that ambient reservoirs serve as constant sources of spore infiltration into indoor residences, office complexes, and healthcare institutions [49]. • Kashi & Beyglu (2015): Observed high concentrations of *Aspergillus* and *Penicillium* across female secondary school classrooms in Eslamshahr. Student aspergillosis symptomatology correlated with mean airborne spore density; classroom overcrowding directly augmented bioaerosol concentrations and subsequent respiratory risks [50].

Table 3: Continued

Razavi Khorasan	• Faridi et al. (2015): Demonstrated that ambient air exchange alongside localized indoor shedding dynamically govern microbial bioaerosol loads across residential care homes and student boarding dormitories [51] • Faridi et al. (2017): Established that acute bioaerosol exposure triggers systemic inflammatory cascades, manifested as significant elevations in circulatory biomarkers—specifically interleukin-6 (IL-6) and white blood cell (WBC) counts—in healthy young adults and elderly populations [52]. • Kashi & Beyglu (2020): Reported Gram-positive bacteria and *Aspergillus flavus* as the predominant indoor bioaerosols within university academic laboratories, with airborne fungal loads remaining directly linked to occupant respiratory symptoms [53]. • Haghighi and Mohammadi (2016): Documented a significant association between indoor fungal burdens and relative humidity within semi-arid public indoor spaces. Engineering controls regulating indoor psychrometric parameters (temperature and humidity) significantly suppressed pathogenic spore viability [54]. • Rostami et al. (2017): Identified yeasts, *Penicillium*, *Alternaria*, *Aspergillus niger*, and *Aspergillus flavus* as the dominant fungal taxa recovered across indoor and outdoor zones of an academic medical center, emphasizing the need for upgraded hospital disinfection protocols [55].
Khuzestan	• Soleimani et al. (2013): Observed significant increases in culturable indoor fungal loads during severe dust storm episodes compared to background baseline days in Ahvaz, establishing atmospheric dust storms as major vectors of indoor biological contamination [56]. • Goudarzi et al. (2014): Documented strong positive correlations between mass particulate concentrations and culturable airborne bacteria across normal, moderate, and severe dust episodes. Elevated cardiopulmonary hospital admissions in Ahvaz were directly associated with sustained particulate surges (PM_{10}) and elevated co-occurring bioaerosol exposures [57]. • Goudarzi et al. (2016): Confirmed that Gram-positive bacteria displayed significantly higher survival and persistence against environmental stressors (notably intense solar UV radiation) during Middle Eastern dust events than Gram-negative [58]. • Harbizadeh et al. (2017): Identified *Staphylococcus* and *Bacillus* as the primary bacterial contaminants in indoor and ambient air at Ahvaz daycare centers. Transitioning from natural window ventilation to sealed mechanical HVAC systems, coupled with certified air purifiers and personal masks during dust surges, was recommended to protect pediatric cohorts [59]. • Fattahinia et al. (2018): Recovered *Cladosporium*, *Alternaria*, *Aspergillus*, *Penicillium*, *Drechslera*, and *Stemphylium* as the predominant ambient mycoflora in Ahvaz. Aerobiological dynamics were strongly modulated by ambient temperature, relative humidity, and wind velocity [60]. • Talepour et al. (2019): Identified the grit chamber of the Ahvaz municipal wastewater treatment plant (WWTP) as the primary emission point source for *Alternaria* spores, highlighting occupational biohazard risks for outdoor wastewater operators [61].
Zanjan	• Rostami et al. (2009): Correlated fungal contamination of commercially sold peanuts with ambient aerobiological and microclimatic conditions in the Zanjan central bazaar; recommended post-harvest thermal roasting, salting, and moisture-controlled storage to inhibit fungal proliferation and mycotoxin accumulation [62].
Sistan and Baluchestan	• Mirzaei et al. (2014): Identified *Staphylococcus aureus* and *Micrococcus* spp. as the dominant bacterial taxa within operating theaters and emergency departments of teaching hospitals in Zahedan. High microbial burdens and taxonomic diversity highlighted the necessity of institutional infection control protocols [63].
Fars	• Pakshir et al. (2007): Recovered *Cladosporium* and *Aspergillus* as the predominant airborne fungal contaminants across Shiraz University of Medical Sciences teaching hospitals. Routine fungal surveillance and protective isolation of high-risk patients were identified as vital safeguards against nosocomial mycoses [64]. • Choobineh (2009): Documented that indoor airborne microbial load in all surveyed hospital wards exceeded recommended occupational thresholds (> 30 CFU/m^3), indicating urgent requirements for engineered hospital air distribution systems [65]. • Abbasi et al. (2017): Identified *Aspergillus niger* as the prevailing bioaerosol in solid waste and material recovery facilities (MRFs) in southern Iran. Mechanical exhaust ventilation alongside mandatory certified particulate respirators was deemed essential to mitigate occupational inhalation hazards [66]. • Dehghani et al. (2018a): Culturable airborne fungi recovered across three distinct seasons at a municipal wastewater treatment plant ranked sequentially as Cephalotrichum, Alternaria, Penicillium, Monilia, and Aspergillus [67]. • Dehghani et al. (2018b): Demonstrated a statistically significant reduction in culturable operating theater bioaerosols directly attributable to standardized surface disinfection and terminal room sterilization protocols [68].
Qazvin	• Dastamooz and Rahmani (2016): Recorded the lowest institutional bioaerosol concentrations in hospital operating suites. Microbial burdens correlated directly with occupant density, clinical movement, and mechanical ventilation efficiency, reinforcing the need for continuous environmental surveillance [69].
Qom	• Azizifar et al. (2009): Utilized an Andersen single-stage impactor to map fungal loads across Kamkar Hospital; minimum concentrations occurred in clinical pathology laboratories, whereas maximum densities were documented in coronary and intensive care units (CCU/ICU). Quantitative bioburdens exceeded health-based reference standards, underscoring secondary nosocomial transmission risks [70].

Table 3: Continued

Kermanshah	correlated with higher mechanical ventilation exchange rates, thereby diluting airborne microbial densities; occupant density remained the primary positive predictor of bacterial shedding [71].
Lorestan	• Sepahvand et al. (2013): Confirmed *Aspergillus* as the most prevalent airborne fungus across five hospital ICUs in Khorramabad. Indoor fungal loads were largely driven by outdoor atmospheric bioaerosols, displaying significant positive correlations with ambient particulate matter, relative humidity, and ambient temperature [72]. • Roudbari et al. (2013): Documented that bioaerosol concentrations surrounding municipal solid waste containers and active landfill trenches significantly exceeded the national outdoor bioaerosol standard (850 CFU/m^3), calling for targeted engineering controls in municipal solid waste collection [73]. • Jahangiri et al. (2015): Observed pronounced spirometric decrements among wastewater treatment plant operators with prolonged cumulative bioaerosol exposure. Escalated incidences of chronic respiratory symptoms and declines in forced expiratory volume were directly attributed to aerosolized endotoxins and wastewater microflora [74]. • Sepahvand et al. (2016): Recorded the lowest mean fungal density in surgical suites (46.4 CFU/m^3) and the highest in infectious disease wards (101.7 CFU/m^3) in Khorramabad hospitals. Dominant isolates (*Aspergillus* and *Penicillium*) pose clinical risks for immunocompromised and post-surgical patients [75].
Mazandaran	• Hedayati et al. (2010): Identified *Aspergillus flavus* as the dominant fungus in both outdoor air and the residences of asthmatic patients across warm, humid coastal zones. The fungus serves as a primary ambient aeroallergen source; targeted indoor mitigation mitigates symptom exacerbations in sensitized individuals [76]. • Ajoudanifar et al. (2011): Isolated *Cladosporium* as the principal airborne fungus in indoor and outdoor microenvironments of rural livestock and poultry farms, demonstrating substantial occupational bioaerosol exposure profiles [77]. • Mirmohammadi and Moghadasi (2011): Recorded mean respirable flour dust concentrations of 30 ± 3 mg/m^3 across traditional and commercial bakeries, identifying allergen-bearing dusts as major etiological agents in baker's asthma and occupational allergic rhinitis [78]. • Foladi et al. (2013): Identified *Cladosporium* as the predominant bioaerosol in enclosed administrative document archives, where sustained fungal accumulation poses occupational respiratory risks to archival personnel [79].
Hamedan	• Hoseinzadeh et al. (2011): Quantified total suspended particles (TSP), PM_{10}, and $PM_{2.5}$ across central intercity transit terminals in Hamedan. Mass concentrations of respirable particulates exceeded permissible health thresholds, demonstrating the necessity of spatial exposure assessment and identifying localized high-exposure microenvironments [80].

and total suspended particles (TSP) others centered on fungal bioaerosols and exposure to organic dust. Consequently, air quality assessment cannot be confined to single-pollutant monitoring; rather, it must encompass an integrated spectrum of chemical, physical, and biological agents tailored to specific emission sources and environmental contexts.

Evaluations of bioaerosols demonstrated a substantial presence of airborne fungi across diverse indoor and outdoor settings. For instance, Ajodanifar et al. quantified airborne fungi in the indoor and outdoor air of poultry and cattle farms in Mazandaran Province, reporting concentrations ranging from 10 to 1,700 CFU/m^3 indoors and 10 to 2,170 CFU/m^3 outdoors, with *Cladosporium*, yeasts, and *Aspergillus* identified as predominant taxa. These findings underscore that livestock and poultry facilities represent critical occupational sources of fungal bioaerosol exposure, highlighting the necessity of incorporating biological surveillance alongside particulate matter monitoring in such settings.

Evidence from administrative environments corroborates this pattern. Foladi et al. assessed administrative archives and reported the presence of airborne genera including *Cladosporium*, *Aspergillus*, and *Penicillium*, with a specific focus on screening for *Stachybotrys chartarum*. These observations highlight the importance of bioaerosol monitoring in buildings where suboptimal maintenance, elevated moisture, or inadequate ventilation facilitate fungal amplification. However, because these investigations primarily quantified environmental exposure without directly assessing clinical endpoints, their findings delineate the extent and magnitude of potential exposure rather than establishing definitive causal relationships between fungal concentrations and respiratory pathologies [79].

Findings concerning particulate matter demonstrate that air contamination extends well beyond biological agents. Hosseinzadeh et al. reported elevated levels of $PM_{2.5}$, PM_{10}, and TSP in intercity bus terminals in Hamadan, utilizing spatial mapping to delineate high-burden hotspots [80]. This highlights the indispensable role of geospatial methodologies in exposure assessment, as aggregate mean values often mask localized spatial gradients and high-risk microenvironments. Coupling quantitative monitoring with spatial tools, such as

Geographic Information Systems (GIS), is therefore vital for identifying pollution clusters and targeting intervention priorities.

Furthermore, Mirmohammadi et al. demonstrated in industrial and traditional bakeries that exposure monitoring must be executed at the personal level and adapted to workplace dynamics; they measured respirable flour dust within workers' breathing zones and evaluated the moderating effects of temperature, relative humidity, and workplace volume. Hence, accurate risk characterization requires examining not merely ambient pollutant concentrations, but also exposure duration, sampling microenvironments, ventilation performance, structural building characteristics, occupational tasks, and emission source profiles [81].

A cross-study synthesis confirms that air quality assessment must be multidimensional. In public and urban environments, monitoring criteria pollutants notably and takes precedence, whereas in occupational and damp indoor environments prone to biological contamination, systematic surveillance of bioaerosols and factors driving microbial amplification is imperative. In alignment with this, the World Health Organization (WHO) identifies continuous, standardized air quality monitoring as an essential prerequisite for identifying pollutant dynamics, informing public health advisories, conducting health impact assessments, and tracking the efficacy of abatement initiatives.

Step 2: Standards and Guideline Values

The reviewed evidence highlights the necessity of benchmarking observed concentrations against health-based guidelines and regulatory standards. The WHO Global Air Quality Guidelines provide health-based benchmarks for criteria pollutants, including $PM_{2.5}$, PM_{10}, ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO). While not legally binding, these values serve as an evidence-based framework for formulating national standards. In its 2021 update, the WHO established guideline values for $PM_{2.5}$ of 5 $\mu g/m^3$ (annual mean) and 15 $\mu g/m^3$ (24-hour mean), and for PM_{10} of 15 $\mu g/m^3$ and 45 $\mu g/m^3$, respectively, reflecting recent epidemiological evidence demonstrating adverse health outcomes at substantially lower exposure thresholds.

Comparing national empirical findings with these guidelines offers critical insights into the public health significance of observed exposures, provided that sampling duration, analytical methodologies, environmental typologies, and the distinction between statutory limits and advisory benchmarks are rigorously accounted for.

Conversely, interpreting biological pollutants such as airborne fungi cannot rely solely on universal quantitative thresholds, as uniform health-based exposure limits remain largely undefined for most bioaerosols. Consequently, bioaerosol evaluations must depend on broader contamination patterns, indoor-to-outdoor (I/O) concentration ratios, source apportionment, building conditions, taxonomic characterization, exposure duration and intensity, and correlated clinical evidence. A critical deficiency highlighted across the literature is the absence of enforceable, context-specific regional standards and action thresholds for bioaerosol assessment across diverse settings.

Step 3: Health Outcomes, Engineering and Administrative Controls, and Mitigation Efficacy

Synthesized data demonstrate that effective prevention must operate proactively across the hierarchy of controls: at the source, along the transmission pathway, and at the individual receptor level. At the source, key measures include emission abatement, facility maintenance, moisture control, elimination of microbial growth substrates, and process modifications that minimize dust generation. Along the pathway, optimized ventilation, engineered airflow distribution, filtration, and preventing outdoor pollutant infiltration can markedly reduce indoor exposure. At the individual level, the proper use of certified respiratory protective equipment serves as an essential final barrier of defense in high-exposure occupational settings.

A salient limitation identified in the domestic literature is that available evidence in Iran predominantly emphasizes exposure characterization and quantification, with very few studies employing pre- and post-intervention designs to evaluate mitigation efficacy. Thus, while existing data strongly support the necessity of surveillance, source control, ventilation optimization, and exposure reduction, they do not yet permit empirical quantification of the relative efficacy of specific interventions.

From a policy perspective, routine and standardized air quality monitoring must be integrated into public health decision-making and regulatory frameworks. The WHO emphasizes that harmonized, high-quality monitoring data are critical for informing stakeholders, conducting health impact assessments, and tracking the performance of environmental interventions. Furthermore, robust air quality standards, reliable monitoring infrastructure, and effective governance mechanisms represent foundational pillars for safeguarding population health.

In summary, the synthesized evidence indicates that systematic air monitoring, context-specific health thresholds, source identification, source containment, mechanical ventilation upgrades, facility engineering, and targeted personal protective equipment collectively constitute a complementary framework for mitigating exposure. To strengthen the empirical evidence base, longitudinal and interventional studies tracking pollutant concentrations and health outcomes before and after control implementation are essential to bridge the gap between documenting environmental hazards and proving the real-world efficacy of remediation

strategies. Preventing individual health impacts remains the ultimate objective of air quality management, wherein regulatory authorities serve an indispensable function in mitigating ambient and indoor environmental degradation.

Given the identified evidence gaps, future research

Table 4: Recent studies on the association between air pollution, climate change, and human health outcomes (including emerging diseases such as COVID-19)

Author(s) & Year	Key Findings
Katoto et al. (2021)	This systematic review synthesized studies published between December 2019 and September 2020 to evaluate the association between short- and long-term exposure to ambient air pollutants and COVID-19 health outcomes. Findings indicated that elevated concentrations of pollutants—specifically $PM_{2.5}$, PM_{10}, NO_2, and O_3—were associated with increased COVID-19 incidence and mortality. This association was supported by stronger evidence for long-term exposure, particularly concerning $PM_{2.5}$ and NO_2. Despite methodological heterogeneity and limitations across the reviewed literature, the authors concluded that curbing anthropogenic emissions and addressing socioeconomic disparities could play a pivotal role in mitigating the burden of respiratory pandemics, including COVID-19 [82].
Juarez et al. (2022)	Synthesizing 63 selected investigations out of over 170,000 screened articles, this systematic review evaluated the interrelationships among air pollution, meteorological conditions, climate change, and COVID-19 outcomes. The findings demonstrated that elevated particulate matter levels (notably $PM_{2.5}$) and other criteria air pollutants, in conjunction with specific climatic patterns, were linked to higher infection rates, increased disease severity, and elevated COVID-19 mortality. Furthermore, these adverse impacts were disproportionately pronounced among socially disadvantaged populations and individuals with pre-existing chronic morbidities, though the strength of association varied geographically. The authors highlighted the necessity of systematic air quality surveillance and the integration of environmental metrics into public health emergency management[83]
Romero Starke et al. (2021)	Evaluating 11 epidemiological studies, this systematic review investigated the influence of ambient temperature and humidity on COVID-19 mortality. Although findings showed some variation across studies, lower temperatures and decreased relative humidity were predominantly associated with increased COVID-19-related mortality. The authors noted that establishing definitive causal links requires future investigations to rigorously control for critical confounders alongside meteorological metrics, including population density, public health containment measures, and exposure lag structures [84].
Lai et al. (2025)	Drawing from a comprehensive review of more than 10,000 articles, this study demonstrated that climate change alters the atmospheric concentrations of particulate matter (PM) and tropospheric ozone through rising temperatures, shifts in precipitation, wind patterns, and other meteorological dynamics. These environmental shifts exacerbate ambient air pollution, amplify the incidence of respiratory and cardiovascular diseases, and widen the global disease burden, disproportionately impacting low-income regions. The authors emphasized the imperative of expanding epidemiological research in underrepresented regions and developing evidence-based mitigation frameworks to minimize health risks [4].
Shoaib et al. (2025)	This study identified ambient air pollution and climate change as synergistic, compounding threats to ecological systems and human health. Elevated concentrations of particulate matter, ozone, and allied pollutants correlate directly with an increased prevalence of respiratory illnesses, cardiovascular events lung cancer, and premature mortality. The authors emphasized the necessity of unified cross-sector emissions abatement policies, accelerated deployment of clean technologies, and reinforced international collaboration to protect public health[85] .
Sharma (2026)	Characterizing climate change as driven primarily by anthropogenic drivers—such as fossil fuel combustion, deforestation, and industrialization—this study detailed how rising global mean temperatures, intensifying heatwaves, droughts, and extreme flooding degrade biodiversity and food security while escalating cardiovascular and respiratory morbidity. The author stressed the urgent need to curtail greenhouse gas emissions, scale up renewable energy infrastructure, advance afforestation

should adopt standardized bioaerosol sampling, identification, and quantification methodologies to facilitate cross-study comparability. Interventional, longitudinal, and prospective cohort studies are imperative to quantitatively characterize exposure-response relationships and delineate the long-term health consequences of bioaerosol exposure. In Iran, studies must progress beyond descriptive contamination profiling toward empirically evaluating the efficacy of preventive and managerial interventions across diverse microenvironments, explicitly controlling for covariates such as occupant density, ventilation parameters, temperature, and relative humidity. Specifically, subsequent investigations should not only quantify bioaerosol concentrations and resolve emission sources, but also quantitatively assess the real-world performance of source controls, enhanced ventilation, high-efficiency filtration, and administrative protocols across varied functional settings particularly healthcare facilities, academic institutions, and occupational environments.

Conclusion

This systematic review synthesized current evidence on ambient and indoor air pollution and bioaerosols, evaluating exposure assessment methodologies, attributable clinical outcomes, and the efficacy of prevention and control measures. The compiled evidence indicates that exposure to complex chemical and biological airborne contaminants is associated with adverse respiratory, cardiovascular, and systemic health outcomes [87-90], with clinical severity governed by pollutant speciation, concentration, exposure duration, intake pathway, and host susceptibility.

At the building and environmental scale, mitigating exposure via source abatement, optimized ventilation, indoor air quality management, rigorous HVAC maintenance, and minimizing ambient pollutant infiltration constitutes the primary line of defense. At the individual level, the proper use of certified personal respiratory protective equipment (RPE) offers vital secondary protection under high-exposure occupational conditions or severe pollution episodes; however, engineering and source-level controls demonstrate substantially greater efficacy in achieving sustainable, long-term exposure reduction.

The existing literature in Iran remains heavily weighted toward descriptive environmental monitoring and exposure characterization [91], revealing a critical empirical gap regarding the rigorous evaluation of preventive interventions, particularly for indoor bioaerosols. Protecting population health requires transitioning from passive monitoring and reporting toward source attribution, active exposure management, and pre- and post-intervention validation of technical and administrative controls. Establishing this evidence base is essential for setting regulatory intervention priorities and developing actionable frameworks to optimize indoor and outdoor air quality.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

AMF and GK contributed equally to all stages of the study, including conceptualization, methodology, literature synthesis, and manuscript drafting.

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Ethical Considerations

Ethical principles including prevention of plagiarism, informed consent, scientific misconduct, data fabrication or falsification, redundant publication, and duplicate submission have been rigorously observed and upheld by the authors.

References

[1] Monteiro A, Figueiredo E, Rodrigues V, Cardoso C, Lopes M, Roebeling P, et al. Air pollution and environmental justice: a systematic literature review on methodological approaches. Heliyon. 2026;12(1):e43215. https://doi.org/10.1016/j.heliyon.2025.e44289

[2] World Health Organization. WHO Global Air Quality Guidelines: Particulate Matter (PM2.5 and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide: Executive Summary. Geneva: WHO; 2021.

[3] Baeza_Romero MT, Dudzinska MR, Amouei Torkmahalleh M, Barros N, Coggins AM, Ruzgar DG, et al. A review of critical residential buildings parameters and activities when investigating indoor air quality and pollutants. Indoor Air. 2022;32(11):e13144. https://doi.org/10.1111/ina.13144

[4] Lai Y, Lu M, Chen G, Fu B, Xu Z, Xin J, et al. Unraveling the complex impact of climate change on air quality in the world. NPJ Clean Air. 2025;1(1):25. https://doi.org/10.1038/s44407-025-00027-4

[5] Amin H, Bertelsen RJ. Climate change and indoor biological exposures: a hidden risk to immune health. Front Public Health. 2025;13:1597881. https://doi.org/10.3389/fpubh.2025.1597881

[6] Gheitasian P, Ebadifard Azar F, Mohseni-Bandpey A, Meserghani M, Shariatmadari E. Evaluation of bacterial bioaerosol diversity and density in the indoor air of elderly care facilities. Environ Health Eng Manag J. 2025;12:1-7. https://doi.org/10.34172/EHEM.1411

[7] Khan A, Karuppayil S. Potential natural disinfectants for

indoor environments. Int J Clin Aromather. 2010;7(1):1-5.
[8] Chen F, Yang X, Mak HK, Chan DW. Photocatalytic oxidation for antimicrobial control in built environment: a brief literature overview. Build Environ. 2010;45(8):1747-1754. https://doi.org/10.1016/j.buildenv.2010.01.024
[9] Mohammadian M, Movahedi MA. Assessment of biological agents in the air of different wards in Imam Khomayni and Shahid Zare hospitals in Sari, 2007. J Mazandaran Univ Med Sci. 2010;20(74):68-73.
[10] Lee SJ, Park JS, Im HT, Jung HI. A microfluidic ATP-bioluminescence sensor for the detection of airborne microbes. Sens Actuators B Chem. 2008;132(2):443-448. https://doi.org/10.1016/j.snb.2007.10.035
[11] Griffiths W, Bennett A, Speight S, Parks S. Determining the performance of a commercial air purification system for reducing airborne contamination using model micro-organisms: a new test methodology. J Hosp Infect. 2005;61(3):242-247. https://doi.org/10.1016/j.jhin.2005.03.004
[12] Maung TZ, Bishop JE, Holt E, Turner AM, Pfrang C. Indoor air pollution and the health of vulnerable groups: a systematic review focused on particulate matter (PM), volatile organic compounds (VOCs) and their effects on children and people with pre-existing lung disease. Int J Environ Res Public Health. 2022;19(14):8752. https://doi.org/10.3390/ijerph19148752
[13] Geravandi S, Takdastan A, Zallaghi E, Vousoghi Niri M, Mohammadi MJ, Saki H, et al. Noise pollution and health effects. Jundishapur J Health Sci. 2015;7(1):1-5. https://doi.org/10.5812/jjhs.25357
[14] Goudarzi G, Geravandi S, Mohammadi MJ, Salmanzadeh S, Vosoughi M, Sahebalzamani M. The relationship between air pollution exposure and chronic obstructive pulmonary disease in Ahvaz, Iran. Jundishapur J Health Sci. 2015;7(1):e27142.
[15] Mainelis G. Bioaerosol sampling: Classical approaches, advances, and perspectives. Aerosol Sci Technol. 2020;54(5):496-519. https://doi.org/10.1080/02786826.2019.1671950
[16] Huang Z, Yu X, Liu Q, Maki T, Alam K, Wang Y, et al. Bioaerosols in the atmosphere: A comprehensive review on detection methods, concentration and influencing factors. Sci Total Environ. 2024;912:168818. https://doi.org/10.1016/j.scitotenv.2023.168818
[17] Rastmanesh A, Boruah JS, Lee MS, Park S. On-site bioaerosol sampling and airborne microorganism detection technologies. Biosensors (Basel). 2024;14(3):122. https://doi.org/10.3390/bios14030122
[18] Kazemnejad A, Moussavi SG, Gholami-Fesharaki M, Salari M, Hamta A, Samadi S. Preventing Methods of Air Pollution Harmful Effects on Police Officers: a Systematic Review Study. J Police Med. 2015;4(2):77-86.
[19] Laripoor M, Samadi M. A review of microbial contamination of air in hospital infections and prevention methods. J Microbiol Knowl. 2010;2(4):1-8.
[20] Suresh Y, Devi MS, Manjari V, Das U. Oxidant stress, antioxidants and nitric oxide in traffic police of Hyderabad, India. Environ Pollut. 2000;109(2):321-325. https://doi.org/10.1016/S0269-7491(99)00254-7
[21] Paulose-Ram R. Cigarette Smoking and Lung Obstruction Among Adults Aged 40-79: United States 2007-2012. Hyattsville (MD): US Department of Health and Human Services; 2015.
[22] Harte CB, Meston CM. Effects of smoking cessation on heart rate variability among long-term male smokers. Int J Behav Med. 2014;21(2):302-309. https://doi.org/10.1007/s12529-013-9295-0
[23] Padma S, Sundaram P. Current practice and recommendation for presurgical cardiac evaluation in patients undergoing noncardiac surgeries. World J Nucl Med. 2014;13(1):6-15. https://doi.org/10.4103/1450-1147.138568
[24] Sarmasti F, Kalantari G, Mahmoodi J. Investigation of education effect on fuel stations workers, attitude, knowledge and practice regarding benzene in 22 area of Tehran city in 2019. J Health. 2019:101-106.
[25] Kaplan GG, Dixon E, Panaccione R, Fong A, Chen L, Szyszkowicz M, et al. Effect of ambient air pollution on the incidence of appendicitis. CMAJ. 2009;181(9):591-597. https://doi.org/10.1503/cmaj.082068
[26] Ananthakrishnan AN, McGinley EL, Binion DG, Saeian K. Ambient air pollution correlates with hospitalizations for inflammatory bowel disease: an ecologic analysis. Inflamm Bowel Dis. 2011;17(5):1138-1145. https://doi.org/10.1002/ibd.21455
[27] Kampa M, Castanas E. Human health effects of air pollution. Environ Pollut. 2008;151(2):362-367. https://doi.org/10.1016/j.envpol.2007.06.012
[28] Burke K, Wei H. Synergistic damage by UVA radiation and pollutants. Toxicol Ind Health. 2009;25(4-5):219-224. https://doi.org/10.1177/0748233709106067
[29] Newman PA, McKenzie R. UV impacts avoided by the Montreal Protocol. Photochem Photobiol Sci. 2011;10(7):1152-1160. https://doi.org/10.1039/c0pp00387e
[30] Valacchi G, Sticozzi C, Pecorelli A, Cervellati F, Cervellati C, Maioli E. Cutaneous responses to environmental stressors. Ann N Y Acad Sci. 2012;1271(1):75-81. https://doi.org/10.1111/j.1749-6632.2012.06724.x
[31] Manie R, Kalantari G, Hosini M. Investigation of heavy metals and total suspended particles in the outside and around air selected parks of Tehran in 2019. In: 8th National Conference on Air and Noise Pollution Management. Tehran: Tehran University; 2020. p. 1-7.
[32] Kazemi A, Ahmadpour E, Naghili B, Zarei M, Jafari A, Mousavi AA. Airborne fungi in Tabriz, comparing airborne and clinical samples of A. fumigatus (2011), survey and literature review. Jundishapur J Microbiol. 2013;6(4):e4955. https://doi.org/10.5812/jjm.4997
[33] Khodabandelou H, Rasoulzadeh Y, Mirzaeei R, Rezaeei MA. Bio-aerosols variety and concentration in different hospital wards of Miandoab City in winter. Med J Tabriz Univ Med Sci. 2016;38(3):58-65.
[34] Nourmoradi H, Nikaeen M, Amin MM, Hatamzadeh M. An Investigation on Bio-aerosol Concentrations in the Different Wards of Hospitals of Isfahan University of Medical Sciences. J Isfahan Med Sch. 2011;29(149):1103-1111.
[35] Taheri S, Golbabaei F. The study of aerosol and bioaerosol in home carpet weaving workshops rural Isfahan. J Health Res. 2011;6(2):351-356.
[36] Mirhoseini SH, Nikaeen M, Khanahmad H, Hatamzadeh M, Hassanzadeh A. Monitoring of airborne bacteria and aerosols in different wards of hospitals-Particle counting usefulness in investigation of airborne bacteria. Ann Agric Environ Med. 2015;22(4):670-673. https://doi.org/10.5604/12321966.1185772
[37] Golshahi J, Sadeghi M, Saqira M, Zavar R, Sadeghifar M, Roohafza H. Exposure to occupational air pollution and cardiac function in workers of the Esfahan Steel Industry, Iran. Environ Sci Pollut Res Int. 2016;23(12):11759-11765. https://doi.org/10.1007/s11356-016-6334-9
[38] Mirhoseini SH, Ariyan F, Mohammadi S. Quantitative and

qualitative monitoring of airborne bacteria and fungi and their relationship with environmental parameters in two selected primary schools. J Arak Univ Med Sci. 2020;22(6):242-251. https://doi.org/10.32598/JAMS.22.6.5931.1

[39] Ghanizadeh F, Godini H. A review of the chemical and biological pollutants in indoor air in hospitals and assessing their effects on the health of patients, staff and visitors. Rev Environ Health. 2018;33(3):231-245. https://doi.org/10.1515/reveh-2018-0011

[40] Tolabi Z, Alimohammadi M, Hassanvand MS, Nabizadeh R, Soleimani H, Zarei A. The investigation of type and concentration of bio-aerosols in the air of surgical rooms: A case study in Shariati hospital, Karaj. MethodsX. 2019;6:641-650. https://doi.org/10.1016/j.mex.2019.03.016

[41] Najafi MS, Khoshakhllagh F, Zamanzadeh SM, Shirazi MH, Samadi M, Hajikhani S. Characteristics of TSP loads during the Middle East springtime dust storm (MESDS) in Western Iran. Arab J Geosci. 2014;7(12):5367-5381. https://doi.org/10.1007/s12517-013-1086-z

[42] Farrokhi S, Gheybi MK, Movahed A, Tahmasebi R, Iranpour D, Fatemi A, et al. Common aeroallergens in patients with asthma and allergic rhinitis living in southwestern part of Iran: based on skin prick test reactivity. Iran J Allergy Asthma Immunol. 2015;14(2):133-138.

[43] Chehregani A, Majde A, Moin M, Gholami M, Shariatzadeh MA, Nassiri H. Increasing allergy potency of Zinnia pollen grains in polluted areas. Ecotoxicol Environ Saf. 2004;58(2):267-272. https://doi.org/10.1016/j.ecoenv.2003.12.004

[44] Nadafi K, Rezaei S, Nabizadeh NR, Younesian M, Jabari H. Density of airborne bacteria in a children's hospital in Tehran. Iran J Environ Health Sci Eng. 2009;6(4):257-262.

[45] Naddafi K, Jabbari H, Hoseini M, Nabizade R, Rahbar M, Yunesian M. Investigation of indoor and outdoor air bacterial density in Tehran subway system. Iran J Environ Health Sci Eng. 2011;8(4):381-386.

[46] Abdollahi A, Mahmoudzadeh S. Microbial profile of air contamination in hospital wards. Iran J Pathol. 2012;7(3):177-182.

[47] Azimi F, Naddafi K, Nabizadeh R, Hassanvand MS, Alimohammadi M, Afhami S, et al. Fungal air quality in hospital rooms: a case study in Tehran, Iran. J Environ Health Sci Eng. 2013;11(1):30. https://doi.org/10.1186/2052-336X-11-30

[48] Hoseini M, Jabbari H, Naddafi K, Nabizadeh R, Rahbar M, Yunesian M, et al. Concentration and distribution characteristics of airborne fungi in indoor and outdoor air of Tehran subway stations. Aerobiologia. 2013;29(3):355-363. https://doi.org/10.1007/s10453-012-9285-8

[49] Shams-Ghahfarokhi M, Aghaei-Gharehbolagh S, Aslani N, Razzaghi-Abyaneh M. Investigation on distribution of airborne fungi in outdoor environment in Tehran, Iran. J Environ Health Sci Eng. 2014;12(1):54. https://doi.org/10.1186/2052-336X-12-54

[50] Kashi G. Investigation of the Bio-aerosols Concentration from High Schools Indoor Air in Islamshahr County in 1392-1393. J Environ Health Eng. 2015.

[51] Faridi S, Hassanvand MS, Naddafi K, Yunesian M, Nabizadeh R, Sowlat MH, et al. Indoor/outdoor relationships of bioaerosol concentrations in a retirement home and a school dormitory. Environ Sci Pollut Res Int. 2015;22(11):8190-8200. https://doi.org/10.1007/s11356-014-3944-y

[52] Faridi S, Naddafi K, Kashani H, Nabizadeh R, Alimohammadi M, Momeniha F, et al. Bioaerosol exposure and circulating biomarkers in a panel of elderly subjects and healthy young adults. Sci Total Environ. 2017;593-594:380-389. https://doi.org/10.1016/j.scitotenv.2017.03.186

[53] Kashi G, Beyglu H. Investigation of Bioaerosols in Laboratories of Islamic Azad University, Tehran, Iran. J Environ Health Eng. 2020. https://doi.org/10.18502/ijph.v49i3.3165

[54] Haghighi MHM, Mohammadzadeh A. Microbial indoor air quality of public places in a semi-dry city in Iran. Int J Trop Med. 2016;11(4):102-107.

[55] Rostami N, Alidadi H, Zarrinfar H, Salehi P. Assessment of indoor and outdoor airborne fungi in an Educational, Research and Treatment Center. Ital J Med. 2017;11(1):52-56. https://doi.org/10.4081/itjm.2016.663

[56] Soleimani Z, Goudarzi G, Naddafi K, Sadeghinejad B, Latifi SM, Parhizgari N, et al. Determination of culturable indoor airborne fungi during normal and dust event days in Ahvaz, Iran. Aerobiologia. 2013;29(2):279-290. https://doi.org/10.1007/s10453-012-9279-6

[57] Goudarzi G, Shirmardi M, Khodarahmi F, Hashemi-Shahraki A, Alavi N, Ankali KA, et al. Particulate matter and bacteria characteristics of the Middle East Dust (MED) storms over Ahvaz, Iran. Aerobiologia. 2014;30(4):345-356. https://doi.org/10.1007/s10453-014-9333-7

[58] Soleimani Z, Goudarzi G, Sorooshian A, Marzouni MB, Maleki H. Impact of Middle Eastern dust storms on indoor and outdoor composition of bioaerosol. Atmos Environ. 2016;138:135-143. https://doi.org/10.1016/j.atmosenv.2016.05.023

[59] Harbizadeh A, Mirzaee SA, Khosravi AD, Shoushtari FS, Goodarzi H, Alavi N, et al. Indoor and outdoor airborne bacterial air quality in day-care centers (DCCs) in greater Ahvaz, Iran. Atmos Environ. 2019;216:116927. https://doi.org/10.1016/j.atmosenv.2019.116927

[60] Fatahinia M, Zarei-Mahmoudabadi A, Shokri H, Ghaymi H. Monitoring of mycoflora in outdoor air of different localities of Ahvaz, Iran. J Mycol Med. 2018;28(1):87-93. https://doi.org/10.1016/j.mycmed.2017.12.002

[61] Talepour N, Hassanvand MS, Abbasi M, Latifi SM, Jaafarzadeh Haghighifard N. Identification allergen Cladosporium spores concentration in the ambient of Ahvaz wastewater treatment plant and their relationship with meteorological variables, Ahvaz, Iran. J Environ Health Eng. 2019. https://doi.org/10.18502/japh.v4i4.2199

[62] Rostami R, Naddafi K, Aghamohamadi A. Survey of peanut fungal contamination and its relationship with ambient conditions in the Bazar of Zanjan. J Environ Health Sci Eng. 2010;7(3):253-260.

[63] Mirzaei R, Shahriary E, Qureshi MI, Rakhshkhorshid A, Khammary A, Mohammadi M. Quantitative and qualitative evaluation of bio-aerosols in surgery rooms and emergency department of an educational hospital. Jundishapur J Microbiol. 2014;7(10):e11688. https://doi.org/10.5812/jjm.11688

[64] Pakshir K, Shekarkhar G, Mostaghni S, Sabayan B, Vaghefi K. Monitoring of airborne fungi in two general hospitals in Shiraz, Southern Iran. Iran J Med Sci. 2007;32(4):227-231.

[65] Choubinch A, Rostami R, Tabatabaei S. Assessment of bioaerosols types and concentration in ambient air of Shiraz University of Medical Sciences educational hospitals, 2008. J Environ Health Sci Eng. 2009;6(3):187-194.

[66] Abbasi FF, Samaei MR, Khodadadi H, Karimi A, Binaee Haghighi A, Ekhlasi J. Investigation of fungal bioaerosols in Shiraz composting facilities during 2017. J Health Sci Surveill Syst. 2017;5(1):7-14.

[67] Dehghani M, Sorooshian A, Ghorbani M, Fazlzadeh M,

Miri M, Badiee P, et al. Seasonal variation in culturable bioaerosols in a wastewater treatment plant. Aerosol Air Qual Res. 2018;18(11):2826-2839. https://doi.org/10.4209/aaqr.2017.11.0466

[68] Dehghani M, Sorooshian A, Nazmara S, Baghani AN, Delikhoon M. Concentration and type of bioaerosols before and after conventional disinfection and sterilization procedures inside hospital operating rooms. Ecotoxicol Environ Saf. 2018;164:277-282. https://doi.org/10.1016/j.ecoenv.2018.08.034

[69] Dastamouz A, Rahmani M. Evaluation of indoor air quality in different hospital wards by bioaerosol sampling and particle counting in 2016. J Occup Hyg Eng. 2018;5(1):53-60. https://doi.org/10.21859/johe-5.1.53

[70] Azizifar M, Jabbari H, Naddafi K, Nabizadeh R, Tabaraie Y, Solg A. A qualitative and quantitative survey on air-transmitted fungal contamination in different wards of Kamkar Hospital in Qom, Iran, in 2007. Iran J Health Environ. 2009;2(2):93-100.

[71] Soltanian M, Mohammadi P, Najafi F, Kazemi S, Asadi F. Study of Airborne Bacterial Density in Surgery and Infectious Wards of Hospitals Affiliated with Kermanshah University Medical Science and its Relationship with Environmental Factors. Iran J Epidemiol. 2018;13(4):308-317.

[72] Sepahvand A, Shams-Ghahfarokhi M, Allameh A, Razzaghi-Abyaneh M. Diversity and distribution patterns of airborne microfungi in indoor and outdoor hospital environments in Khorramabad, Southwest Iran. Jundishapur J Microbiol. 2013;6(2):141-147. https://doi.org/10.5812/jjm.5074

[73] Roodbari A, Naddafi K, Javid A. Measurements of bioaerosols in the air around the facilities of waste collection and disposal. Environ Prot Eng. 2013;39(4):105-112. https://doi.org/10.37190/epe130409

[74] Jahangiri M, Neghab M, Nasiri G, Aghabeigi M, Khademain V, Rostami R, et al. Respiratory Disorders Associated with Occupational Inhalational Exposure to Bioaerosols among Wastewater Treatment Workers of Petrochemical Complexes. Int J Occup Environ Med. 2015;6(1):41-48. https://doi.org/10.15171/ijoem.2015.458

[75] Sepahvand A, Ghahfarokhi M, Omidi Y, Tarrahi MJ, Rashidi R, Basiri H. Investigation of fungal bioaerosols and particulate matter in the teaching-medical hospitals of Khorramabad City, Iran during 2015. Iran J Health Environ. 2016;9(1):115-126.

[76] Hedayati MT, Mayahi S, Denning DW. A study on Aspergillus species in houses of asthmatic patients from Sari City, Iran and a brief review of the health effects of exposure to indoor Aspergillus. Environ Monit Assess. 2010;168(1-4):481-487. https://doi.org/10.1007/s10661-009-1128-x

[77] Ajoudanifar H, Hedayati MT, Mayahi S, Khosravi A, Mousavi B. Volumetric assessment of airborne indoor and outdoor fungi at poultry and cattle houses in the Mazandaran Province, Iran. Arh Hig Rada Toksikol. 2011;62(3):243-247. https://doi.org/10.2478/10004-1254-62-2011-2099

[78] Mirmohammadi S, Yadegarfar G, Jalahi H. Indoor air pollution modeling based on flour dust in industrial and traditional bakeries. World Appl Sci J. 2011;12(7):951-957.

[79] Foladi S, Hedayati M, Shokohi T, Mayahi S. Study on fungi in archives of offices, with a particular focus on Stachybotrys chartarum. J Mycol Med. 2013;23(4):242-246. https://doi.org/10.1016/j.mycmed.2013.09.003

[80] Hoseinzadeh E, Samarghandi MR, Ghorbani Shahna F, Chavoshi E. Isoconcentration mapping of particulate matter in Hamedan intercity bus stations. Water Environ J. 2013;27(3):418-424. https://doi.org/10.1111/j.1747-6593.2012.00351.x

[81] Mirmohammadi S. Indoor air pollution modeling based on flour dust in industrial and traditional bakeries. World Appl Sci J. 2011;12(7):951-957.

[82] Katoto PD, Brand AS, Bakan B, Obadia PM, Kuhangana C, Kayembe-Kitenge T, et al. Acute and chronic exposure to air pollution in relation with incidence, prevalence, severity and mortality of COVID-19: a rapid systematic review. Environ Health. 2021;20(1):41. https://doi.org/10.1186/s12940-021-00714-1

[83] Juarez PD, Ramesh A, Hood DB, Alcendor DJ, Valdez RB, Aramandla MP, et al. The effects of air pollution, meteorological parameters, and climate change on COVID-19 comorbidity and health disparities: A systematic review. Environ Chem Ecotoxicol. 2022;4:194-210. https://doi.org/10.1016/j.enceco.2022.10.002

[84] Romero Starke K, Mauer R, Karskens E, Pretzsch A, Reissig D, Nienhaus A, et al. The effect of ambient environmental conditions on COVID-19 mortality: a systematic review. Int J Environ Res Public Health. 2021;18(12):6665. https://doi.org/10.3390/ijerph18126665

[85] Shoaib M, Pechuho T, Safdar M, Islam R, Durrani F, Rashid S, et al. Air pollution and climate change: A dual threat to ecosystems and human health. J Med Health Sci Rev. 2025;2(2):45-58. https://doi.org/10.62019/7w0pmn06

[86] Sharma A. A Comprehensive Review on Climate Change: Causes, Impacts, and Mitigation Strategies. Int J Multidiscip Res. 2026;8(1):1-15. https://doi.org/10.36948/ijfmr.2026.v08i01.67594

[87] Rajagopalan S, Al-Kindi SG, Brook RD. Air pollution and cardiovascular disease. J Am Coll Cardiol. 2018;72(17):2054-2070. https://doi.org/10.1016/j.jacc.2018.07.099

[88] Lippmann M, Chen LC, Gordon T, Ito K, Thurston GD. National Particle Component Toxicity (NPACT) Initiative: Integrated epidemiologic and toxicologic studies of the health effects of particulate matter components. Res Rep Health Eff Inst. 2013;177:5-13.

[89] Wang M, Beelen R, Stafoggia M, Raaschou-Nielsen O, Andersen ZJ, Hoffmann B, et al. Long-term exposure to elemental constituents of particulate matter and cardiovascular mortality in 19 European cohorts: results from the ESCAPE and TRANSPHORM projects. Environ Int. 2014;66:97-106. https://doi.org/10.1016/j.envint.2014.01.026

[90] Chau TT, Wang KY. An association between air pollution and daily most frequently visits of eighteen outpatient diseases in an industrial city. Sci Rep. 2020;10(1):2321. https://doi.org/10.1038/s41598-020-58721-0

[91] Hasanvand MS, Naddafi K, Faridi S, Momeniha F. A systematic review of studies conducted in Iran on air pollution in Iran. Tehran: Environmental Research Institute; 2017.