Journal of Health Information and Librarianship

ISSN: 2408-6614
e-ISSN: 2672-4839

Unseen Threat: Mapping the Diversity of Fungal Contaminants in Bayero University's Library

Zam'a Mohammed Alhassan,[1*] Lukman Ibraheem Diso,[1] Atiku Abashe Maidabino,[1] and Mukthar Muhammad Dauda[1]

ABSTRACT

Background: Fungal contamination in libraries endangers both the preservation of print collections and the health of staff and users. This study investigated the prevalence, species diversity, and environmental determinants of fungal contamination in Bayero University Kano (BUK) Libraries.
Method: A quantitative cross-sectional design was employed, combining microbiological analysis with a staff survey. A total of 145 book swab samples and six (6) air samples (collected in both morning and afternoon) were obtained from the Circulation, Reference, and Serials sections of Bayero University Library. Environmental parameters (temperature and humidity) were measured, while a questionnaire was administered to 176 staff, of which 165 were returned (92.1% response rate).
Results: Out of 145 book samples, 79 (54.5%) tested positive for fungal contamination, with the highest load observed in the Circulation section (mean count: $9.5 \pm 2.75 \times 10^5$ CFU/ml). Five species were identified: Aspergillus flavus, A. fumigatus, A. niger, Penicillium chrysogenum, and P. griseofulvum, with A. niger dominant. Indoor air samples showed significant fungal presence, particularly in the Circulation and Reference sections. Relative humidity ranged from 62%–69%, and temperatures from 27.2°C to 29.1°C, both favourable for fungal growth. Poor ventilation, dust accumulation, and overcrowded shelving were associated with higher contamination. Visible signs of biodeterioration included spot patches (68.8%), fuzzy growth (66.5%), and discoloration (45.3%). Staff reported frequent symptoms linked to fungal exposure, such as sneezing (80.3%), dry throat (70.2%), and eye irritation (66.1%).
Conclusion: Fungal contamination is a major environmental and occupational health risk in BUK Libraries. Interventions such as improved ventilation, dehumidification, routine disinfection, microbial monitoring, and staff training are essential for safeguarding health and preserving library resources.

[1]Department of Library and Information Sciences, Bayero University, Kano, Nigeria | [*]zamaalhassan.lib@buk.edu.ng | lidisoq01@yahoo.com | maidabinnoforyou@gmail.com | mdmukhtar.mcb@buk.edu.ng

[*]https://orcid.org/0000-0002-1206-0073

Manuscript Received: 2nd October 2024
Manuscript Accepted: 12th December 2025

Introduction

Libraries, as custodians of printed knowledge, play a pivotal role in the preservation and dissemination of academic resources. However, the physical environment of libraries, particularly in regions with high humidity and fluctuating temperatures, can predispose collections to microbial contamination, particularly from fungi. Fungal contamination is not only a major contributor to the bio-deterioration of valuable print resources but also poses significant health risks to library staff and users due to airborne spores and allergenic compounds. Academic libraries in Nigeria, including those at Bayero University Kano (BUK), house large volumes of paper-based resources, many of which are stored under suboptimal environmental conditions. These conditions, characterised by dust accumulation, poor ventilation, lack of air-conditioning, and inadequate maintenance, promote the proliferation of fungal spores on surfaces and in the air. Previous studies have identified Aspergillus and Penicillium species as common fungal contaminants in libraries, with known implications for paper degradation and respiratory ailments in individuals (Camargo-Caicedo et al., 2024; Sequeira et al., 2019; Borrego et al., 2022).

Despite the evident threats, there is limited empirical data on the extent and nature of fungal contamination in Nigerian university libraries as well as its health implications. This study was therefore conducted to fill this gap by assessing fungal contamination levels, identifying fungal species in the BUK library environment, examining the influence of environmental factors, documenting visible signs of contamination on print resources, and evaluating potential health risks to library staff.

Statement of the Problem

Fungal contamination poses a significant threat to the preservation of print resources and the health of individuals within library environments. In academic institutions like Bayero University, the library houses extensive collections of print materials that are vulnerable to fungal infestation, especially under favorable environmental conditions such as high humidity, poor ventilation, and fluctuating temperatures. Despite this risk, there is a lack of empirical data on the extent of fungal contamination across different sections of Bayero University Library. Additionally, the specific fungal species present, the observable physical signs of contamination, and the associated health implications for library staff remain under-investigated. This gap in knowledge hinders the development of effective preservation strategies and health safety measures. Therefore, a systematic investigation is necessary to assess the level and diversity of fungal contamination, examine the influence of environmental factors, and evaluate the potential health risks to inform proper mitigation and management practices within the university libraries.

Research Questions

This study answered the following research questions:

1. What is the level of fungal contamination on print resources sampled in different sections of Bayero University Library?

2. What species of fungi are present in the library environment of Bayero University print resources?

3. What species of fungi are present in the library environment of Bayero University, indoor air samples?

4. What are the prevailing environmental conditions (humidity, temperature, and ventilation) in the library sections examined?

5. What maintenance and housekeeping practices are present in different sections of Bayero University Kano Library in relation to fungal contamination?

6. What are the physical indicators of fungal contamination on print resources in Bayero University Library?

7. What are the potential health challenges of fungal exposure for library staff?

Literature Review

Fungi play a significant role in the biodeterioration of library materials and the deterioration of indoor air quality in heritage environments. As highly adaptable eukaryotic organisms, fungi thrive in diverse ecological niches and utilise external organic substrates, particularly cellulose and lignin, which are abundant in paper-based collections (Naranjo-Ortiz & Gabaldon, 2019). Their resilience in low-nutrient and low-moisture environments is facilitated by dormant spores and resistant reproductive structures, allowing them to withstand adverse conditions. Many of these species are xerophilic, enabling growth at low relative humidity (RH) and making them well-adapted to library environments where they can remain dormant and reactivate when moisture becomes available (Mensah-Attipoe & Toyinbo, 2019).

Environmental conditions play a crucial role in fungal proliferation in indoor cultural institutions. Wu et al. (2021) demonstrate that poor ventilation and inadequate environmental control directly influence fungal diversity and abundance in libraries. Relative humidity and temperature were found to be the most significant determinants of fungal presence, while human occupancy and accumulated dust acted as secondary drivers. Correspondingly, Upadhyay (2023) highlights that high moisture, poor air circulation, and dust accumulation on paper, textiles, and wooden fittings create optimal conditions for fungal growth. The release of airborne spores, hyphal fragments, microbial volatile organic compounds (MVOCs), and mycotoxins contributes to indoor air pollution and poses health risks, especially to vulnerable groups.

Certain storage systems, such as compact movable shelving (Compactus), create microclimates favourable to xerophilic fungi. Research shows that even when ambient climate parameters meet

recommended standards, micro-enclosed environments in Compactus units can harbour unique fungal species not commonly encountered elsewhere. Species such as Eurotium halophilicum have been identified as dominant xerophilic agents in these micro-environments, colonising leather, parchment, and textile-bound volumes and producing characteristic white mycelial spots (Montanari et al., 2012). These findings reveal the capacity of fungi to exploit microclimatic variations, thereby threatening the integrity of historical collections.

Fungal biodeterioration is driven principally by powerful enzymatic systems that degrade structural components of library materials. Many fungal species possess cellulases, hemicellulases, proteases, amylases, gelatinases, and pectinases that break down cellulose, starch, gelatin, and proteins found in paper and leather bindings. Abdel-Maksoud et al. (2022) reported strong hydrolytic enzyme activity among multiple isolates from historical manuscripts, confirming their active involvement in material degradation. This enzymatic action results in weakening of paper fibres, structural decay, and surface erosion of bindings.

In addition to enzymatic destruction, fungi produce secondary metabolites, including organic acids and pigments that cause aesthetic deterioration such as staining, discoloration, and foxing. Foxing, typically seen as reddish-brown spots, is strongly associated with xerophilic and pigment-producing species of Aspergillus, Penicillium, and Chaetomium that thrive in dry, dusty library conditions (Arai, 2000). Such damage diminishes the visual, archival, and scholarly value of affected materials (Stratigaki et al., 2024). Prominent biodeteriogenic genera Aspergillus, Penicillium, Cladosporium, and Trichoderma are consistently documented in library collections across various climates and are known for strong cellulolytic potential (Gadd et al., 2024; Sequeira et al., 2019). Trichoderma species, in particular, exhibit aggressive enzymatic actions that accelerate fibre degradation and the overall deterioration process.

Fungal contamination extends beyond surface biodeterioration to influence indoor air quality through dispersal of spores and bioaerosols. Camargo-Caicedo et al. (2024) report that airborne spores are easily disseminated across library spaces, promoting cross-contamination and contributing to the microbial ecology of indoor cultural environments. Dust on books serves as an important reservoir for dormant spores, which can reactivate when favourable conditions return (Osifeso et al., 2025). Exposure to these bioaerosols has been linked to respiratory illnesses, including asthma, allergic rhinitis, hypersensitivity pneumonitis, and upper respiratory tract infections (Basi et al., 2016; Kwon et al., 2021; Mendell et al., 2011). In addition, reactivated spores can cause allergic dermatitis and conjunctivitis among library staff and users (Apetrei et al., 2009).

Certain fungal species produce toxic metabolites that pose even greater health threats. Stachybotrys chartarum, for example, releases mycotoxins, beta-glucans, ergosterol, and MVOCs that can induce severe immune reactions and neurotoxic symptoms (Pestka et al., 2021). These harmful compounds contribute to the aetiology of Sick Building Syndrome (SBS), characterised by headaches, fatigue, respiratory problems, and cognitive impairment, particularly in damp or poorly maintained library buildings (Nag, 2018). This intersection of cultural heritage preservation and occupational health underscores the urgency of implementing robust environmental control and risk management strategies (Ansah et al., 2024).

Taken together, the reviewed literature reveals that fungal contamination in libraries is driven by a combination of biological adaptability and environmental permissiveness. Xerophilic and cellulolytic fungi colonise library materials through enzymatic degradation, pigment production, and spore dispersal. Microclimatic variations, especially in enclosed shelving systems, exacerbate this risk even when overall environmental controls are adequate. The consequences extend beyond physical deterioration of collections to substantial public health risks through airborne fungal components and toxic metabolites.

The dual challenge of preserving fragile library materials and safeguarding human health demands an integrated and preventive approach. Key interventions include routine microbial surveillance, strict relative humidity control, enhanced ventilation and air filtration, and staff training on fungal risks and mitigation practices. Addressing both the biological mechanisms and environmental drivers of fungal colonisation will enable libraries to protect their collections while ensuring a safe environment for users and staff

Methods

This study adopts a positivist research paradigm, emphasising objectivity, measurement, and empirical investigation of fungal contamination in Bayero University Library. A quantitative research methodology was employed, allowing for the collection and analysis of numerical data to determine the extent and nature of fungal presence across different sections of the library. A descriptive cross-sectional survey design was combined with experimental microbiological analysis. The cross-sectional survey facilitated the collection of data at a specific point in time, enabling the assessment of fungal contamination levels, species diversity, and environmental conditions such as humidity, temperature, and ventilation. The experimental component involved the collection and laboratory analysis of print resource swabs and air samples, using standard mycological techniques to isolate and identify fungal species (See Appendix I). Environmental parameters were measured in situ using hygrometers and thermometers, while a structured questionnaire was administered to library staff to gather data on physical conditions of print resources, and the potential health risk associated with their exposure to fungal contaminants (See Appendix 2). These multiple steps enhanced the reliability and validity of the findings by providing a comprehensive understanding of the extent of fungal contamination, the influence of environmental factors, the observable indicators on print materials, and the potential occupational health risks.

Furthermore, Laboratory analyses of book swabs and indoor air samples were used to address Research Questions 1 to 4, assessing fungal contamination, species diversity, and environmental conditions. Observational assessments of library sections were conducted for Research Question 5 to evaluate maintenance and housekeeping practices. A structured questionnaire was administered to library staff to collect data on physical indicators of fungal contamination and potential health challenges for Research Questions 6 and 7

Results

This section presents the findings obtained from the fieldwork and laboratory analyses carried out in the study. The results are organized according to the research questions that guided the investigation.

Research Question 1. What is the level of fungal contamination on print resources sampled in different sections of Bayero University Library?.

The data presented in Table 1 reveal a high level of fungal contamination across all three sections of the Bayero University Library. A total of 94 book swab samples were collected from the Circulation section, of which 51 samples (54.3%) tested positive for fungal growth. The fungal counts in this section ranged from 4.0×10^5 to 15.0×10^5 CFU/ml, with a mean count of $9.5 \pm 2.75 \times 10^5$ CFU/ml, indicating a high degree of contamination. Similarly, in the Reference section, 15 samples were collected, and 8 (53.3%) were positive for fungal contamination. The fungal load in this section ranged from 2.0×10^5 to 10.0×10^5 CFU/ml, with a mean of $6.0 \pm 2.0 \times 10^5$ CFU/ml. The Serials section also exhibited significant contamination, with 20 out of 36 samples (55.6%) testing positive. Fungal counts in this area ranged from 2.5×10^5 to 11.0×10^5 CFU/ml, and the mean count was $6.75 \pm 2.13 \times 10^5$ CFU/ml. Overall, all sections showed a high prevalence of fungal contamination, with positive sample rates exceeding 50%.

Table 1: Fungal Counts (CFU/ml) of the Print Resources Swab Samples

Site	Sections	No of Samples Collected	No of Positive Samples (% Positive)	Range of Fungal Counts (10^5 cfu/ml)	Mean Count ± SD (10^5 cfu/ml)	Remark (Level of Contamination based on the no of sample collected)
Buk Library	Circulation	94 (64.8%)	51 (64.6%)	4.0 - 15.0	9.5 ± 2.75	High
	Reference	15 (10.3%)	8 (10.1%)	2.0 - 10.0	6.0 ± 2.0	High
	Serials	36 (24.8%)	20 (25.3%)	2.5 - 11.0	6.75 ± 2.13	High
Total		145 (100%)	79 (100%)	2.0-15.0	6.0 ± 2.75	High

Research Question 2. What species of fungi are present in the library environment of Bayero University, including print resources and air samples?

Table 2 presents the frequency distribution of fungal species isolated from book samples across three sections of the BUK library: Circulation, Reference, and Serials. A total of 117 fungal isolates were recorded, with the Circulation section contributing the highest number (64 isolates, 54.7%), followed by the Serials (27 isolates, 23.1%) and Reference (26 isolates, 22.2%) sections. Among the ten identified fungal species, only five were detected: Aspergillus flavus, A. fumigatus, A. niger, Penicillium chrysogenum, and P. griseofulvum. The most frequently isolated species was A. niger (48 isolates), predominantly found in the Circulation section. A. flavus and A. fumigatus were also common, with 18 and 25 isolates, respectively, and were distributed across all sections but more concentrated in Circulation. P. chrysogenum appeared in all three sections, while P. griseofulvum was restricted to the Reference and Serials sections. Notably, A. nidulans, A. versicolor, Arthrographis, Cladosporium, and P. notatum were not detected in any samples.

Research Question 3. What species of fungi are present in the library environment of Bayero University, indoor air samples?

Table 3 presents the frequency distribution of fungal species identified from indoor air samples collected across three sections of the Bayero University Kano (BUK) Library Circulation, Reference, and Serials. A total of 10 fungal isolates were recovered from the air samples, indicating a moderate but diverse fungal presence in the library's indoor environment. The fungal species isolated include Aspergillus flavus, A. fumigatus, A. niger, Penicillium chrysogenum, and P. janczewskii.

Research Question 4. What are the prevailing environmental conditions (humidity, temperature, and ventilation) in the library sections examined?

Table 4 shows that temperature variations remain relatively minor throughout the day, and relative humidity decreases slightly in the afternoon. This reduction may limit microbial growth to some extent; however, the conditions remain favourable for fungal contamination. Compared to other libraries, BUK Library maintains moderate environmental conditions that support microbial survival, particularly in the serials and circulation sections.

Table 2: Frequency Distribution of Fungal Species from Book Samples

SITES	1	2	3	4	5	6	7	8	9	10	TOTAL
Buk library circulation	14 (77.8)	14 (56.0)	0 (0.0)	26 (54.2)	0 (0.0)	0 (0.0)	0 (0.0)	10 (50.0)	0 (0.0)	0 (0.0)	64 (54.7)
Buk library reference	0 (0.0)	7 (28.0)	0 (0.0)	13 (27.1)	0 (0.0)	0 (0.0)	0 (0.0)	3 (50.0)	3 (0.5)	0 (0.0)	26 (22.2)
Buk library serials	4 (22.2)	4 (16.0)	0 (0.0)	9 (18.8)	0 (0.0)	0 (0.0)	0 (0.0)	7 (35.0)	3 (0.5)	0 (0.0)	27 (23.1)
Total	18 (100)	25(100)	0(0.0)	48 (100)	0(0.0)	0(0.0)	0(0.0)	20 (100)	6 (100)	0(0.0)	117(100)

Key: 1= *A. flavus,* 2= *A. fumigatus*, 3= *A. nidulans,* 4= *A. niger,* 5= *A. versicolor,* 6=*Arthrographis,* 7=*Cladosporium,* 8= *P. chrysogenum,* 9= *P. griseofulvum,* 10=*P.notatum*

Table 3: Frequency Distribution of Fungal Species in Indoor Air Samples

Site	A. flavus	A. fumigatus	A. niger	A. versicolor	P. chrysogenum	P. janczewskii	Total
Buk library circulation	2(50.0)	0(0.0)	2(100)	0(0.0)	0(0.0)	0(0.0)	4(40.0)
Buk library reference	2(50.0)	1(33.3)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(30.0)
Buk library serials	0(0.0)	2(66.7)	0(0.0)	0(0.0)	1(100)	0(0.0)	3(30.0)
Total	4 (100)	3(100)	2(100)	0(100)	1(100)	0 (100)	10(100)

Key: 1= *A. flavus,* 2= *A. fumigatus*, 3= *A. nidulans,* 4= *A. niger,* 5= *A. versicolor,* 6=*Arthrographis,* 7=*Cladosporium,* 8= *P. chrysogenum,* 9= *P. griseofulvum,* 10=*P.notatu*

Table 4: Temperature and Relative Humidity (RH) Levels in Bayero University Kano Library

Collection Site	Morning Temp (°C)	Morning RH (%)	Afternoon Temp (°C)	Afternoon RH (%)	Potential Fungal Contamination Risks
BUK Circulation	28.1	69.0	28.9	67.0	- High humidity (67-69%) promotes fungal growth on books and surfaces. - Slight temperature rise in the afternoon creates ideal conditions for fungal sporulation. - The combination of warm temperature and humidity accelerates biodeterioration of print materials.

Collection Site	Morning Temp (°C)	Morning RH (%)	Afternoon Temp (°C)	Afternoon RH (%)	Potential Fungal Contamination Risks
BUK Reference	28.1	69.0	29.1	62.0	- High morning humidity (69%) increases moisture retention on book pages. - Afternoon humidity drop (62%) may reduce condensation but still supports fungal persistence. - Elevated temperature (29.1°C) facilitates fungal metabolism and enzymatic degradation of paper-based materials.
BUK Serials	27.2	69.0	28.6	64.0	- Slightly lower morning temperature (27.2°C) may slow initial fungal colonization but does not prevent it. - Afternoon rise to 28.6°C with 64% RH remains within the optimal range for fungal growth. - Dark spots and discoloration observed in serial collections correlate with prolonged high humidity exposure.

Research Question 5. What maintenance and housekeeping practices are present in different sections of Bayero University Kano Library in relation to fungal contamination?

Table 5 reveals that observational data from BUK Library indicate that dust accumulation, poor sanitation, lack of HVAC systems, and improper book arrangement are key factors contributing to fungal contamination. The Circulation and Reference sections show high risk due to congested shelves, old and dusty books, and uncontrolled humidity. The Serials section shows signs of active fungal deterioration, such as dark spots on pages and debris. Thus, inadequate environmental controls and poor maintenance practices increase the library's vulnerability to fungal growth.

Table 5: Maintenance and housekeeping practices

Library Section	Maintenance Conditions	Potential Fungal Contamination Risks
Circulation	- Dust accumulation on shelves -Congested book arrangement - Mutilated book covers - Adequate lighting - No AC or humidifiers - Good airflow but no HVAC - Inadequate shelf spacing - Proper reading table spacing	- High dust accumulation provides a habitat for fungal spores - Congested books restrict airflow, trapping moisture and promoting fungal growth - Lack of AC or humidifiers results in uncontrolled humidity, increasing fungal proliferation - Inadequate shelf spacing may lead to poor air circulation, increasing contamination risk
Reference	- Dust accumulation on shelves and books - Presence of old reference books - Good ventilation - Comfortable seating	- Dusty surfaces and old books increase fungal colonization risk - Poor sanitation contributes to microbial contamination - Lack of HVAC systems allows fungal spores to persist and spread

	- Poor sanitation - Average lighting - No HVAC	- Average lighting may not deter fungal growth in hidden areas
Serials	- Well-displayed journals - Dusty, brownish back issues - Dark spots on pages - Debris in collections - Average lighting and ventilation	- Dusty and aged journal issues create ideal conditions for fungal colonization - Dark spots on pages suggest fungal deterioration - Presence of debris in collections may indicate active microbial contamination - Average lighting and ventilation may not be sufficient to prevent fungal spread

Research Question 6. What are the physical indicators of fungal contamination on print resources in Bayero University Library?

To assess the visible signs of fungal contamination on print materials, library staff were asked to indicate all the physical conditions they had observed on the sampled books. Respondents could select more than one option, which explains why the percentages in the table do not sum to 100%. Table 6 reveals widespread physical indicators of fungal contamination in BUK Library. The most frequently observed condition was patches of spots on book pages (68.8%), followed by fuzzy growth on books (66.5%), which indicates active fungal colonization. Discoloration of book pages was reported by 45.3% of respondents, often a sign of chemical breakdown of paper caused by prolonged fungal activity. Lastly, powdery flaking on book covers (37.3%) suggests either dried fungal spores or material degradation. These findings highlight that fungal contamination is evident through multiple physical signs, with respondents often observing more than one type on the same print resources. The presence of such visible indicators suggests that environmental conditions in the library may not be adequately controlled, creating a favourable setting for fungal growth.

Table 6: Physical Indicators of Fungal Contamination in BUK Library

Observed Condition	**No of respondents (n=165)**	**Occurrence (%)**
Patches of spots on book pages	113	68.8
Presence of fuzzy growth on books	110	66.5
Discoloration of book pages	75	45.3
Powdery flaking layer on the cover of the books	62	37.3

Research Question 7. What are the potential health challenges of fungal exposure for library staff?

To understand the potential health risks associated with fungal exposure, library staff were asked to indicate all symptoms or health challenges they had experienced that they believed were related to their work environment. Respondents could select more than one option, which is why the percentages in the table do not sum to 100%.

Table 7 reveals that a substantial number of library staff are experiencing symptoms commonly associated with fungal exposure. Sneezing (80.3%) and dry throat (70.2%) were the most frequently reported symptoms, indicating a strong likelihood of exposure to airborne fungal spores or dust particles. Eye irritation and itching (66.1%) and irritated, stuffy, or running nose (60.1%) were also highly prevalent, suggesting that fungal allergens may be affecting mucous membranes and respiratory function. Feeling heavy-headed or having headaches (58.3%) and coughing (45.5%)

further accentuate the respiratory burden potentially linked to fungal contamination in the library environment. Less frequently reported symptoms, such as upper airways irritation (21.9%), fatigue and dizziness (18.6%), and sinusitis-like conditions (28.3%), still affect a notable portion of the staff. These findings indicate that exposure to fungal contaminants in the library may pose multiple health risks, with many staff members reporting more than one symptom

Table 7: Potential Health Challenges of Fungal Exposure to Library Staff

S/N	Statement	No of Respondents (n=165)	Yes (%)
1.	Upper airways irritation	36	21.9%
2.	Sneezing	133	80.3%
3.	Coughing	75	45.5%
4.	irritated, stuffy, Running nose	99	60.1%
5.	Sinusitis (similar to common cold)	47	28.3%
6.	Eye irritation and itching	109	66.1%
7.	Fatigue and dizziness	31	18.6%
8.	feeling heavy headed / headache	96	58.3%
9.	Dry throat	116	70.2%

Note: Values represent the number and percentage of respondents who answered "Yes" to each health-related symptom. Percentages were calculated based on the total number of returned questionnaires (n = 165).

Discussion of Findings

This section interprets and contextualizes the results presented in the findings of the study, linking them to the study objectives and relevant literature. The discussion goes beyond merely reporting the data, exploring the meaning, patterns, and implications of the findings. It highlights how the observed levels of fungal contamination, species diversity, environmental conditions, physical indicators, and health challenges relate to existing knowledge and the specific context of Bayero University Library to provide a deeper understanding of the factors contributing to fungal proliferation and its potential impact on library materials and staff wellbeing.

Prevalence and Distribution of Fungal Contamination in Book Samples

The findings demonstrate that fungal contamination is widespread across the major sections of BUK Library. This pattern aligns with previous studies showing that library materials, especially in high-use areas, are highly vulnerable to fungal colonization due to frequent handling, dust accumulation, and fluctuating environmental conditions (El Jaddaoui et al., 2023; Reis-Menezes et al., 2011; Chadeganipour et al., 2011). The contamination patterns observed across Circulation, Reference, and Serials sections are consistent with the notion that poor environmental regulation, especially high humidity and inadequate ventilation, enhance fungal proliferation in libraries. These results reinforce earlier reports that fungal levels exceeding acceptable thresholds pose both preservation and health concerns in indoor environments (Camargo-Caicedo et al., 2024).

Frequency and Distribution of Fungal Species

The dominance of Aspergillus and Penicillium species on book surfaces is consistent with global research showing that these genera are the most common contaminants in libraries (Camargo-Caicedo et al., 2024; El Jaddaoui et al., 2023). The prevalence of A. niger, A. flavus, and A. fumigatus confirms their adaptability to cellulose-rich materials and dusty environments. Their distribution across sections suggests environmental

uniformity in conditions that favour fungal survival. The absence of other expected species such as A. versicolor and Cladosporium may be due to environmental constraints or competitive exclusion, a trend documented by similar studies.

Fungal Contamination in Indoor Air

The presence of airborne fungal species that mirror those found on book surfaces indicates a strong interaction between settled and aerosolized spores. This supports previous findings that poor ventilation and high user activity facilitate the resuspension of fungal spores in library environments (Borrego et al., 2022). Although airborne levels appeared moderate, their similarity to surface isolates suggests continuous circulation of spores, posing potential health and preservation risks.

Microclimatic Conditions Favouring Fungal Growth

The microclimatic conditions recorded across library sections were favourable for fungal growth, especially the consistently high relative humidity. Earlier studies have emphasized that humidity levels above acceptable limits directly promote fungal germination, colonization, and deterioration of library materials (Derksen et al, 2024; Camargo-Caicedo et al., 2024). Thus, the environmental profile of BUK Library provides a strong explanatory basis for the contamination patterns observed.

Maintenance Condition and Practices as Risk Factors Fungal Contamination

The identified structural deficiencies, such as overcrowded shelves, poor ventilation, dust accumulation, and lack of air-conditioning, further explain the widespread fungal contamination. Similar risk factors have been documented in several library studies where poor maintenance and inadequate environmental controls contribute significantly to biodeterioration (Tabatabaei et al., 2020). These findings highlight the need for improved infrastructure and preservation practices.

Physical Indicators of Fungal Contamination

Reports of visible fungal indicators such as spots, discoloration, fuzzy growth, and powdery residues align with classical symptoms of biodeterioration described in literature (Arai, 2000; Florian, 2002). These manifestations reflect ongoing or historical fungal activity and confirm the environmental suitability for fungal persistence. The prevalence of these indicators suggests insufficient preventive conservation measures and reinforces concerns raised by previous research on the vulnerability of poorly regulated library environments (Olatokun, 2008).

Potential Health Challenges of Exposure to Fungal Contaminants for Library Staff

The health-related symptoms reported by library staff, including respiratory irritation, allergic reactions, and headaches, correspond with documented effects of exposure to indoor fungal spores. Past studies have similarly reported that environments contaminated with Aspergillus and Penicillium species often trigger allergic and respiratory responses (Al-Shaarani & Pecoraro, 2024; Mousavi et al., 2016; Khan & Karuppayil, 2012). The overlap between symptoms observed in this study and those in previous literature suggests that exposure to fungal spores in poorly ventilated workspaces poses a significant occupational health risk. These results highlight the need for routine environmental monitoring and improved indoor air quality management in libraries.

Conclusion and Recommendation

The findings of this study revealed a significant presence of fungal contamination in the Bayero University Kano Library, particularly in the circulation and serials sections. With over half of the print samples testing positive for fungal growth and the identification of dominant species such as Aspergillus niger and Penicillium chrysogenum, the study confirms that current environmental conditions in the library, marked by high humidity, inadequate ventilation, and poor sanitation, facilitate microbial proliferation. The prevalence of physical signs of fungal growth on books and the reported health symptoms among staff, such as sneezing, dry throat, and eye irritation, further emphasize the severity of the issue. These findings highlight the dual impact of fungal contamination

on both library preservation and occupational health. To mitigate these risks, there is an urgent need for libraries to adopt comprehensive environmental control measures, including the installation of Heating Ventilation Air Conditioning systems, regular environmental monitoring, and scheduled disinfection of library collections and spaces. Staff training and health surveillance should also be prioritized to reduce occupational exposure and enhance awareness of microbial hazards in the workplace.

Ultimately, this study is expected to inform evidence-based preservation strategies and occupational safety protocols for library environments in Nigeria and similar settings, as well as contribute to the growing body of knowledge on indoor environmental quality in libraries and stress the importance of integrating preservation science with public health interventions in academic institutions.

Recommendation Based on the Findings

These recommendations are based on the study's results and are meant to help improve the care of library materials, control fungal contamination, and ensure a safer environment for library staff and users.

1. Environmental Monitoring and Controls: Regular monitoring of temperature and relative humidity (RH) to keep RH below 60% to reduce fungal growth. Also, Installation of HVAC or dehumidification systems to regulate indoor climate, especially in the Circulation, Reference, and Serials sections.

2. Cleaning and Maintenance: Implement routine deep cleaning and dust removal in high-risk areas to minimize fungal spore accumulation. Also, reorganize bookshelves for improved airflow and reduced humidity buildup.

3. Disinfection and Mould Control: Standardize disinfection protocols using sodium hypochlorite and hydrogen peroxide on high-touch surfaces and bookshelves. Also, apply Mould Prevention Techniques, such as UV treatment and vacuum drying, for older and sensitive books.

4. Ventilation and Air Filtration: Upgrade ventilation systems with HEPA filters to reduce airborne fungal spores. Also, regular maintenance of air ducts and filters to prevent microbial buildup.

5. Staff Training and Awareness: Provide regular staff training on fungal contamination risks, safe handling of materials, and Mold Identification. Likewise, promote hygiene practices with hand sanitizers and signage to reduce user contamination.

6. Structural and Physical Improvements: Improve library infrastructure by enhancing ventilation, lighting, and shelving in high-risk areas like Reference and Serials sections. Conduct regular inspections to identify and address damp areas or structural issues conducive to fungal growth.

7. Collaboration with Experts: Collaborate with the Microbiology and Environmental Health departments for ongoing fungal monitoring and staff training.

8. Policy and Institutional Support: Develop a formal policy on microbial contamination control in the library, with institutional backing and funding for implementation.

References

Abdel-Maksoud, G., Abdel-Nasser, M., Sultan, M. H., Eid, A. M., Alotaibi, S. H., Hassan, S. E., & Fouda, A. (2022). Fungal biodeterioration of a historical manuscript dating back to the 14th century: An insight into various fungal strains and their enzymatic activities. Life, 12(11), 1821. https://doi.org/10.3390/life12111821

Al-Shaarani, A. A. Q. A., & Pecoraro, L. (2024). A review of pathogenic airborne fungi and bacteria: Unveiling occurrence, sources, and profound human health implication. Frontiers in Microbiology, 15. https://doi.org/10.3389/fmicb.2024.1428415

Ansah, E. W., Amoadu, M., Obeng, P., & Sarfo, J. O. (2024). Health systems response to climate change adaptation: A scoping review of global

evidence. BMC Public Health, 24(1), 2015. https://doi.org/10.1186/s12889-024-19459-w

Apetrei, I., Drăgănescu, G., Popescu, I., Carp-Cărare, C., Guguianu, E., Mihaescu, T., Ștefanache, A., Cretu, C., & Patraș, X. (2009). Possible cause of allergy for the librarians: Books manipulation and ventilation as sources of fungus spores spreading. Aerobiologia, 25, 159–166. https://doi.org/10.1007/s10453-009-9121-y

Baxi, S. N., Portnoy, J. M., Larenas-Linnemann, D., Phipatanakul, W., & Environmental Allergens Workgroup. (2016). Exposure and health effects of fungi on humans. The Journal of Allergy and Clinical Immunology: In Practice, 4(3), 396–408. https://doi.org/10.1016/j.jaip.2016.01.008

Borrego, S., & Perdomo, I. (2016). Mycotoxin-producing fungi in archival repositories: Identification and health risks. International Biodeterioration & Biodegradation, 110, 143–149.

Borrego, S., Vivar, I., & Molina, A. (2022). Air- and dustborne fungi in repositories of the National Archive of the Republic of Cuba. Microbial Cell, 9(5), 103–122. https://doi.org/10.15698/mic2022.05.776

Camargo-Caicedo, Y., Borja Pérez, H., Muñoz Fuentes, M., Vergara-Vásquez, E., & Vélez-Pereira, A. M. (2024). Biodeterioration risk assessment in libraries by airborne fungal spores. Journal of Fungi, 10(10), 680. https://doi.org/10.3390/jof10100680

Chadeganipour, M., Ojaghi, R., Rafiei, H., Afshar, M., & Hashemi, S. T. (2011). Bio-deterioration of library materials: Study of fungi threatening printed materials of libraries in Isfahan University of Medical Sciences. Journal of Jundishapur Microbiology. Retrieved from http://www.jjmicrobiol.com/index.php/jjm

Derksen, K., Brimblecombe, P., Pinar, G., Waldherr, M., Graf, A., Haltrich, M., Querner, P., & Sterflinger, K. (2024). Fungal biodeterioration risk in monastic libraries without climate control. Microorganisms, 12, Article 1450. https://doi.org/10.3390/microorganisms12071450

El Jaddaoui, I., Ghazal, H., & Bennett, J. W. (2023). Mold in paradise: A review of fungi found in libraries. Journal of Fungi, 9(11), 1061. https://doi.org/10.3390/jof9111061

Florian, M. L. (2002). Fungal facts: Solving fungal problems in heritage collections. Archetype Publications.

Gallo, F. (2003). Fungi in libraries: A silent threat to cultural heritage. Journal of Cultural Heritage, 4(3), 237–243.

Khan, A. A. H., & Karuppayil, S. M. (2012). Fungal pollution of indoor environments and its management. Saudi Journal of Biological Sciences, 19(4), 405–426. https://doi.org/10.1016/j.sjbs.2012.06.002

Kwon, J. H., Wi, C. I., Seol, H. Y., Park, M., King, K., Ryu, E., Sohn, S., Liu, H., & Juhn, Y. J. (2021). Risk, mechanisms and implications of asthma-associated infectious and inflammatory multimorbidities (AIMs) among individuals with asthma: A systematic review and a case study. Allergy, Asthma & Immunology Research, 13(5), 697–718. https://doi.org/10.4168/aair.2021.13.5.697

Mensah-Attipoe, J., & Toyinbo, O. (2019). Fungal growth and aerosolization from various conditions and materials. In IntechOpen. https://doi.org/10.5772/intechopen.81565

Montanari, M., Melloni, V., Pinzari, F., & Innocenti, G. (2012). Fungal biodeterioration of historical library materials stored in Compactus movable shelves. International Biodeterioration & Biodegradation, 75, 83–88. https://doi.org/10.1016/j.ibiod.2012.03.011

Mousavi, B., Hedayati, M. T., Hedayati, N., Ilkit, M., & Syedmousavi, S. (2016). Aspergillus species in indoor environments and their possible occupational and public health hazards. Current Medical Mycology, 2(1), 36–42. https://doi.org/10.18869/acadpub.cmm.2.1.36

Nag, P. K. (2018). Sick building syndrome and other building-related illnesses. In Office Buildings: Health, Safety and Environment (pp. 53–103). https://doi.org/10.1007/978-981-13-2577-9_3

Naranjo-Ortiz, M. A., & Gabaldón, T. (2019). Fungal evolution: Major ecological adaptations and evolutionary transitions. Biological Reviews, 94(4), 1443–1476. https://doi.org/10.1111/brv.12510

Nunes, C., Martins, M. L., & Lima, N. (2013). Microbiological assessment of indoor air quality in archive repositories. Environmental Monitoring and Assessment, 185(9), 7647–7655.

Olatokun, W. (2008). A survey of preservation and conservation practices and techniques in Nigerian university libraries. Libres, 18.

Osifeso, O. O., Umoren, O., Akinwunmi, K. A., Amusan, O., Okonkwo, C. F., & Kemele, F. (2025). Health risk of exposure to microbial contamination in settled indoor dust from selected homes in a police barrack. Dutse Journal of Pure and Applied Sciences, 11, 119–128.

Pestka, J., Yike, I., Dearborn, D., Ward, M., & Harkema, J. (2008). Stachybotrys chartarum, trichothecene mycotoxins, and damp building-related illness: New insights into a public health enigma. Toxicological Sciences, 104, 4–26. https://doi.org/10.1093/toxsci/kfm284

Pinzari, F., & Gutarowska, B. (2021). Fungi in libraries and archives: An invisible threat to documentary heritage. In B. Gutarowska (Ed.), Fungal biodeterioration of cultural heritage (pp. 45–78). Springer.

Rakotonirainy, M. S., & Lavédrine, B. (2005). Airborne fungi in libraries and archives: A review of fungal biodiversity and control measures. International Biodeterioration & Biodegradation, 55(3), 165–174.

Reis-Menezes, A., Gambale, W., & Giudice, M. (2011). A survey of fungal contamination on books in public libraries with mechanical and natural ventilation. Indoor and Built Environment, 20(3), 393–399. https://doi.org/10.1177/1420326X11409449

Sequeira, S., Macedo, M., & Pinheiro, A. (2019). Fungi in archives, libraries, and museums: A review on paper conservation and human health. Critical Reviews in Microbiology, 45(6), 686–700. https://doi.org/10.1080/1040841X.2019.1690420

Szczepanowska, H. M., & Lovett, R. (1992). Air quality and the preservation of library collections. Library & Archival Security, 11(1), 21–33.

Tabatabaei, Z., Rafiee, A., Abbasi, A., Mehdizadeh, A., Morovati, R., & Hoseini, M. (2020). Investigation of fungal contamination in indoor air and on surfaces of traditional public baths in a historical city. Journal of Environmental Health Science & Engineering, 18(2), 925–932. https://doi.org/10.1007/s40201-020-00516-6

Upadhyay, R. (2023). Impact of fungi on indoor air quality: Health hazards and management strategies. In Indoor Air Quality Assessment for Sustainable Built Environment (pp. [page range if known]). Springer. https://doi.org/10.1007/978-981-19-9103-5_24

Valentin, N. (2003). Fungal metabolic activity and discoloration in library collections. Studies in Conservation, 48(1), 45–54.

Wu, D., Zhang, Y., Zhao, C., Li, A., Hou, L., Tian, Y., Xiong, J., & Gao, R. (2021). Temporal variation of airborne fungi in university library rooms and its relation to environmental parameters and potential confounders. Environmental Science and Pollution Research, 28(11), 14068–14079. https://doi.org/10.1007/s11356-020-11582-6

Zyska, B. (1997). Fungi isolated from library materials: A review of their potential to damage paper-based documents. International Biodeterioration & Biodegradation, 40(1), 43–51.

APPENDIX 1

Book surfaces were swabbed with normal saline, indoor air was collected using an air sampler with a membrane filter, and all samples were cultured and examined in the lab to identify fungal contamination. Samples were taken from the Circulation, Reference, and Serials sections of the library using two methods:

(1) swabbing book surfaces, and (2) collecting indoor air with an air sampler impactor.

1. Collecting Samples from Books:

- A sterile cotton swab was moistened with normal saline.
- The surfaces of selected books such as covers, edges, and pages were gently swabbed.
- After swabbing, the swab was placed into a sterile universal bottle, properly labelled, and taken to the laboratory.

2. Collecting Indoor Air Samples

- An air sampler impactor fitted with a membrane filter was used.
- The device pulled a measured volume of air through the membrane filter, trapping airborne fungal spores.
- After sampling, the membrane filter was removed, placed in a sterile container, labelled, and transported to the laboratory.

3. Laboratory Work

a. Preparing and Growing the Samples

- Swabs were streaked onto Sabouraud Dextrose Agar (SDA) plates.
- The membrane filters from the air sampler were placed directly onto SDA plates.
- All plates were incubated at 25–28°C for 3–7 days.
- Fungal colonies were checked daily.

b. Identifying the Fungi

- Colonies were examined first by their colour, texture, and growth pattern.
- A small portion of each colony was stained with Lactophenol Cotton Blue and viewed under a microscope.
- The shapes of spores and structures were compared with standard identification guides to determine the fungal species.

APPENDIX 2

QUESTIONNAIRE: FUNGAL CONTAMINATION AND HEALTH EFFECTS IN BUK LIBRARY

Instructions: Please answer all questions based on your personal observations and experiences in the library. You may select more than one option where applicable.

Section A: Physical Indicators of Fungal Contamination on Books

1. Which of the following signs of fungal contamination have you observed on books in your section? (Tick all that apply)

S/N	Observable Conditions	Tick
1	Patches of spots on book pages	
2	Presence of fuzzy or cotton-like growth on books	
3	Discoloration of book pages	
4	Powdery or flaking layer on book covers	
5	Other (please specify)	

Section B: Potential Health Challenges Related to Fungal Exposure

2. Have you experienced any of the following health symptoms that you believe may be related to your work in the library? (Tick all that apply)

S/N	Potential Health Challenges	Tick
1	Sneezing	
2	Dry throat	
3	Eye irritation or itching	
4	Irritated, stuffy, or running nose	
5	Feeling heavy-headed / headache	
6	Coughing	
7	Upper airway irritation	
8	Sinusitis-like symptoms (similar to common cold)	
9	Fatigue or dizziness	