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Evaluation Study

Assessment of Microbiological Air Quality in Primary Schools in Albania

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ABSTRACT

Microbiological contamination of indoor air in school environments represents a significant public health issue, particularly for children, who are more susceptible to respiratory diseases and allergic conditions. The aim of this study was to evaluate levels of exposure to microbiological air pollution in primary schools in Albania and to contribute to protecting students' health and to standardizing indoor air quality monitoring in educational settings. A cross-sectional study was conducted using both active and passive air sampling techniques. Air samples were cultured on selective media, including Plate Count Agar (PCA), Czapek Agar, Meat-Peptone Agar (MPA), and Potato Dextrose Agar (PDA). Sampling was performed in 29 primary schools across five Albanian districts: Fier, Kukës, Malësi e Madhe, Korçë, and Vlorë. Total microbial and fungal loads were analyzed and compared among different school environments and districts. The findings demonstrated considerable variability in total microbial and fungal concentrations among districts and indoor school areas. The predominant fungal genera identified were *Aspergillus* spp., *Penicillium* spp., *Mucor* spp., and *Cladosporium* spp. Higher fungal contamination levels were observed in schools located in areas with dense vegetation, while local climatic conditions appeared to influence the distribution of microbial contaminants. Indoor air quality in school environments requires continuous monitoring, as prolonged exposure to microbiological contaminants may adversely affect students' respiratory health. The results emphasize the need for preventive strategies and for establishing national guidelines for indoor air quality management in primary schools.

INTRODUCTION

Microbiological contamination of indoor air is widely recognized as an important public health issue, particularly in enclosed environments where people spend prolonged periods, such as schools, hospitals, and office buildings. Indoor airborne microorganisms, including bacteria, fungi, and yeasts, may adversely affect human health by causing respiratory infections, allergic reactions, asthma exacerbation, and other toxic effects (1, 2). Children are considered a particularly vulnerable population due to their developing immune systems and the considerable amount of time they spend in school environments, which increases their exposure to indoor air contaminants (3-6).

Previous studies have demonstrated that microbiological air quality in schools is influenced by multiple factors, including ventilation efficiency, building characteristics, occupancy density, cleaning and disinfection practices, the presence of surrounding vegetation, and local climatic conditions (4-6). Recent research conducted in educational settings after 2020 has highlighted that seasonal variation and inadequate ventilation significantly contribute to increased concentrations of airborne bacteria and fungi, with many classrooms exceeding recommended guideline values (7-10). These findings emphasize the need for continuous monitoring of indoor air quality in schools as a preventive public health measure.

Fungi are among the most critical components of indoor bioaerosols due to their ability to produce small, easily inhalable spores. Exposure to airborne fungal spores has been associated with allergic sensitization, asthma development, and other chronic respiratory symptoms in children (9, 10). Studies conducted in primary schools and kindergartens worldwide consistently report the predominance of fungal genera such as *Aspergillus*, *Penicillium*, *Cladosporium*, *Mucor*, and *Alternaria*, reflecting both outdoor sources and indoor environmental conditions (7, 9). Although advances in microbiological and molecular techniques have expanded the understanding of indoor microbial diversity, culture-based methods remain widely used for routine monitoring and regulatory purposes (11).

The COVID-19 pandemic has renewed attention to indoor air quality, including microbiological contamination, particularly in school environments. Recent studies have shown that changes in cleaning frequency, disinfection practices, occupancy patterns, and ventilation strategies during the pandemic significantly influenced the concentration and composition of airborne microorganisms in classrooms (12, 13). These findings underscore the importance of standardized monitoring approaches that combine active and passive air sampling methods to accurately assess microbial exposure in educational buildings (14-16).

Despite the growing international evidence, data on microbiological indoor air quality in school environments remain limited in several regions, including Albania. To date, there is a lack of systematic, region-specific studies evaluating airborne microbial loads in Albanian primary schools across different climatic zones. Such data are essential for establishing baseline exposure levels, identifying predominant microbial taxa, and supporting the development of national guidelines and preventive strategies. Therefore, the aim of the present study was to evaluate microbiological air contamination in nine-year primary schools across multiple districts in Albania using both active and passive air sampling methods, contributing to evidence-based indoor air quality management and the protection of students' health (17, 18).

MATERIALS AND METHODS

Study Design and Study Area

A cross-sectional observational study was conducted to assess microbiological contamination of indoor and outdoor air in primary school environments. The study included 29 primary schools in nine-year programs located in five districts of Albania: Fier, Kukës, Malësi e Madhe, Korçë, and Vlorë. These districts were selected to represent different geographical and climatic conditions, including coastal, mountainous, and inland regions. Air sampling was conducted from February to May 2025, encompassing a range of seasonal and meteorological conditions.

Eligibility Criteria

Public nine-year primary schools operating during the study period and granting authorization for participation were included. Schools undergoing major renovation or with restricted access to sampling areas were excluded. Sampling locations were selected from regularly occupied indoor and outdoor school environments.

Sampling Strategy and Study Settings

Air sampling was performed in both indoor and outdoor environments of each school. Indoor sampling sites included classrooms and corridors, while outdoor samples were collected from schoolyards. Sampling locations were standardized, with Petri dishes positioned approximately 1 m above ground level and at an appropriate distance from walls and other obstacles, in accordance with established bioaerosol sampling guidelines. Sampling was conducted during regular school hours to reflect typical exposure conditions.

Microbiological Air Sampling Methods

Two complementary air sampling techniques were employed:

- Passive sampling: the sedimentation (settle plate) method was used, allowing airborne microorganisms to naturally deposit onto exposed Petri dishes over a one-hour period.
- Active sampling: active air sampling was performed by promoting airflow to enhance the collection of airborne microorganisms onto culture media, providing a more comprehensive assessment of microbial presence.

The use of both methods enabled a qualitative and quantitative description of airborne microbial contamination in school environments.

Culture Media and Microbial Identification

Air samples were cultured on selective and non-selective media, including Plate Count Agar (PCA) for total viable bacterial counts, Meat Peptone Agar (MPA) for bacterial growth, and Czapek Agar and Potato Dextrose Agar (PDA) for fungal isolation. After incubation, microbial colonies were enumerated and identified based on macroscopic and microscopic characteristics. Particular attention was paid to the identification of predominant fungal genera.

Quantification of Microbial Load

Microbial air contamination was expressed as colony-forming units per cubic meter of air (CFU/m^3). Calculations were performed using established mathematical models, including the Polish, Omelianski, and Braz formulas, depending on the sampling technique applied.

Data Items

Collected data included total bacterial and fungal concentrations (CFU/m^3), identification of dominant fungal genera, sampling environment (indoor or outdoor), and district location. Data were used to describe contamination levels across school environments.

Risk of Bias Assessment

To reduce potential bias, sampling procedures, culture conditions, and identification criteria were standardized across all schools. All samples were collected during similar time frames and under comparable operational conditions.

Data Analysis

Data analysis was descriptive in nature. Microbial contamination levels were summarized using absolute values, ranges, and mean concentrations where appropriate. Results were presented to illustrate the distribution and variation of microbiological air pollution across different school environments and districts, without inferential statistical testing.

RESULTS

Table I summarizes the microbial load detected in five primary schools in the city of Korçë. The results show variability in airborne microbial contamination among the investigated schools and culture media.

Higher bacterial loads were observed on Plate Count Agar (PCA), with colony counts exceeding 100 per plate in both Demokacia and Ismail Qemali schools, at both the initial observation and after 48 hours of incubation. In contrast, the *Thoma Gërmenji* school exhibited the lowest microbial contamination, with colony numbers generally below 45 on both PCA and Czapek Agar (CAPEK).

Moderate contamination levels were recorded in *Naim Veqilharxhi* and *Naim Frashëri* schools. Fungal growth on CAPEK media was generally lower than bacterial counts; however, an increase in fungal colonies after 48 hours was observed in *Naim Frashëri* school, indicating favorable conditions for fungal development.

Overall, bacterial contamination predominated over fungal contamination across all schools. The consistent presence of red- and yellow-pigmented colonies suggests a widespread distribution of common airborne microorganisms in the school environments of Korçë.

Table I. *Microbial load in five primary schools of Korçë city.*

School	Medium	Colonies on Plate	Notes	Colonies on Plate (after 48 hours)	Notes
DEMOKRACIA	PCA-1	113 (avg. 109)	Red and yellow pigmented colonies	120 (avg. 122)	Red and yellow pigmented colonies
	PCA-2	104	Red and yellow pigmented colonies	124	Red and yellow pigmented colonies
	CAPEK-1	47 (avg. 53)		47	
	CAPEK-2	59	Yellow pigmented colonies	59	Yellow pigmented colonies
N. VEQILHARXHI	PCA-1	78 (avg. 78)	Red and yellow pigmented colonies	80 (avg. 82)	Red and yellow pigmented colonies
				84	Red and yellow pigmented colonies
	PCA-2	78	Red and yellow pigmented colonies	39 (avg. 43)	Red and yellow pigmented colonies
	CAPEK-1	39 (avg. 43)	Red and yellow pigmented colonies	46	Red and yellow pigmented colonies
	CAPEK-2	46	Red and yellow pigmented colonies	29 (avg. 36)	Red and yellow pigmented colonies
TH. GERMENJI	PCA-1	29 (avg. 36)	Red and yellow pigmented colonies	43	Red and yellow pigmented colonies

	PCA-2	43	Red and yellow pigmented colonies	29 (avg. 30)	Red and yellow pigmented colonies
	CAPEK-1	29 (avg. 30)	Red and yellow pigmented colonies	30	Yellow pigmented colonies
	CAPEK-2	30	Yellow pigmented colonies	62 (avg. 63)	Red and yellow pigmented colonies
NAIM FRASHERI	PCA-1	59 (avg. 57)	Red and yellow pigmented colonies	64	Red and yellow pigmented colonies
	PCA-2	55	Red and yellow pigmented colonies	17 (avg. 23)	Red and yellow pigmented colonies
	CAPEK-1	17 (avg. 23)	Red and yellow pigmented colonies	28	Red and yellow pigmented colonies
	CAPEK-2	28	Red and yellow pigmented colonies	89 (avg. 95)	Red and yellow pigmented colonies
ISMAIL QEMALI	PCA-1	89 (avg. 95)	Red and yellow pigmented colonies	100	Red and yellow pigmented colonies

Figure 1 illustrates the distribution of microbial loads isolated from air samples collected in primary schools of the Korçë district, expressed as the number of microorganisms per Petri dish. The graphical representation confirms the variability of microbial contamination among the investigated schools.

Higher microbial loads were predominantly observed on PCA plates after 48 hours of incubation (blue bars), indicating a greater prevalence of airborne bacteria compared to fungi. Plates counted after 48 hours (maroon bars) showed a similar trend, reflecting sustained microbial viability over time. In contrast, fungal loads detected on CAPEK plates (green bars) were consistently lower across most schools, although increased fungal growth was evident in selected environments.

Overall, the figure highlights the predominance of bacterial contamination over fungal contamination in the examined school environments and supports the observed heterogeneity of microbiological air quality within the Korçë district.

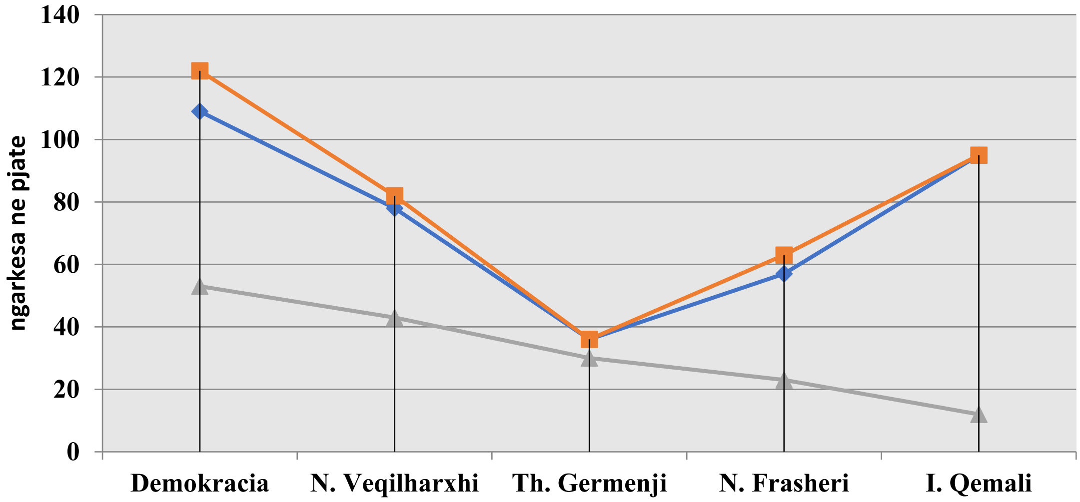

Figure 1. *Graphical representation of the number of isolated microbial loads in schools of the Korçë district (number of microorganisms per Petri dish). *Blue color: load on PCA plates after 48 hours of incubation; *Orange color: load on plates after 48 hours of counting; *Green color: load on CAPEK plates where fungi predominate.*

Table II presents the fungal load and relative contribution of fungi to the total microbial contamination in five primary schools in the city of Korçë. Overall, fungal contamination represented a variable proportion of the total microbial load across the investigated schools.

The highest relative fungal contribution was observed in *Ismail Qemali* school, where fungi accounted for 41.6% of the total microbial load, followed by *Thoma Gërmenji* school with 33.3%. Lower fungal proportions were observed in Naim Frashëri, Naim Veqilharxhi, and Demokacia schools, where fungi accounted for less than 25% of the total microbial load.

Across all schools, the predominant fungal genera identified were *Aspergillus*, *Penicillium*, *Mucor*, and *Rhizopus*, which are commonly reported as dominant components of indoor airborne mycobiota. The presence of these genera indicates typical environmental fungal contamination associated with indoor-outdoor air exchange.

Overall, the results demonstrate heterogeneity in fungal contamination levels among schools, with fungi contributing variably to total microbial air pollution in the Korçë district.

Table II. *Fungal load results in five primary schools of Korçë city.*

Schools Korçë	Medium	Colonies per Plate	Notes (Fungi % of total load and dominant species)
DEMOKRACIA	CAPEK-1	47 (avg. 53), (12 fungi)	22.6% fungi - *Fungi imperfecti*, *Aspergillus terreus*, *Penicillium* spp.
	CAPEK-2	59	Yellow pigmented colonies
N. VEQILHARXHI	CAPEK-1	39 (avg. 43), (8 fungi)	Red and yellow pigmented colonies; 18.6% fungi - *Fungi imperfecti*, *Aspergillus terreus*, *Penicillium* spp.
	CAPEK-2	46	Red and yellow pigmented colonies

TH. GERMENJI	CAPEK-1	29 (avg. 30), (10 fungi)	Red and yellow pigmented colonies; 33.3% fungi - *Mucor* spp., *Penicillium* spp.
	CAPEK-2	30	Yellow pigmented colonies
NAIM FRASHERI	CAPEK-1	17 (avg. 23), (3 fungi)	Red and yellow pigmented colonies; 13.0% fungi - *Mucor* spp., *Penicillium* spp., *Rhizopus nigricans*
	CAPEK-2	28	Red and yellow pigmented colonies
ISMAIL QEMALI	CAPEK-1	23 (avg. 12), (5 fungi)	Red and yellow pigmented colonies; 41.6% fungi - *Aspergillus* spp., *Mucor hiemalis*, *Mucor* spp., *Penicillium* spp.
	CAPEK-2	1	Red and yellow pigmented colonies

Table III shows the microbial and fungal loads in five primary schools of Vlorë. Bacterial contamination on PCA plates was generally high, with colony counts exceeding 100 colonies per plate in most schools, indicating a predominant presence of airborne bacteria.

Fungal contamination, assessed on CAPEK plates and expressed as a percentage of the total microbial load, varied widely among schools. The highest relative fungal loads were observed in *28 Nëntori* and *Muço Delo* schools (85.7%), whereas lower proportions were detected in *Rilindja*, *Ali Demi*, and *Teli Ndini* schools (13-34.6%).

The dominant fungal genera identified across all schools included *Mucor*, *Aspergillus*, and *Candida*, consistent with typical indoor fungal communities in educational settings. Notably, *Mucor spp.* was the most frequently isolated genus, often accounting for the largest proportion of fungal colonies.

Overall, these results demonstrate heterogeneous microbial contamination in Vlorë schools, with bacterial loads predominating and fungal contributions varying according to school-specific environmental conditions.

Table III. *Results from five primary schools in the city of Vlorë (average number of colonies per Petri Dish).*

School	Medium	Colonies per Plate	Notes	Colonies per Plate (48h)	Notes (Fungi % of total load and dominant species)
RILINDJA	PCA	103	Colonies pigmented red and yellow	27	18.5% fungi - *Mucor* spp.
	CAPEK	27	Various colonies, lightly pigmented	36	30.5% fungi - *Mucor* spp., *Mucor mucedo*, *Aspergillus terreus*
28 NENTORI	PCA-1	104	Colonies pigmented red and yellow	7	85.7% fungi - *Mucor* spp., *Aspergillus terreus*
	CAPEK	36	Various colonies	23	27.7% fungi - *Mucor hiemalis*, *Mucor mucedo*, *Aspergillus* spp.

4 HERONJTE	PCA-1	101	Colonies pigmented red and yellow	43	18.6% fungi - *Mucor* spp., *Aspergillus niger*, *Aspergillus terreus*
	CAPEK	7	Various colonies	26	34.6% fungi - predominantly *Aspergillus terreus* and *Candida* spp.
ALI DEMI	PCA-1	117 (avg. 92)	Colonies pigmented red and yellow	15	13.3% fungi - *Aspergillus niger*, *Mucor* spp.
	PCA-2	66	Colonies pigmented red and yellow		
	CAPEK-1	23 (avg. 33)	Various colonies	27	18.5% fungi - *Mucor* spp.
	CAPEK-2	43	Various colonies	36	30.5% fungi - *Mucor* spp., *Mucor mucedo*, *Aspergillus terreus*
MUÇO DELO	PCA	106	Colonies pigmented red and yellow	7	85.7% fungi - *Mucor* spp., *Aspergillus terreus*
	CAPEK	26	Colonies pigmented red and yellow	23	27.7% fungi - *Mucor hiemalis*, *Mucor mucedo*, *Aspergillus* spp.
TELI NDINI	PCA	111	Colonies pigmented red and yellow	43	18.6% fungi - *Mucor* spp., *Aspergillus niger*, *Aspergillus terreus*
	CAPEK	15	Various colonies, lightly pigmented	26	34.6% fungi - predominantly *Aspergillus terreus* and *Candida* spp.

Figure 2 illustrates the distribution of microbial loads in primary schools of Vlorë, expressed as the average number of microorganisms per Petri dish. The graph confirms that bacterial contamination, as indicated by PCA plates after 48 hours of incubation (blue bars), predominates across all schools.

Fungal contamination, shown on CAPEK plates (maroon bars), varied considerably between schools. The highest fungal loads were observed in *28 Nëntori* and *Muço Delo* schools, consistent with the corresponding high fungal proportions reported in Table III. In contrast, *Rilindja*, *Ali Demi*, and *Teli Ndini* schools showed lower fungal loads, highlighting heterogeneity in fungal air contamination.

Overall, Figure 2 supports the observation that bacterial presence is generally higher than fungal contamination in Vlorë schools, while the relative contribution of fungi is influenced by school-specific environmental conditions.

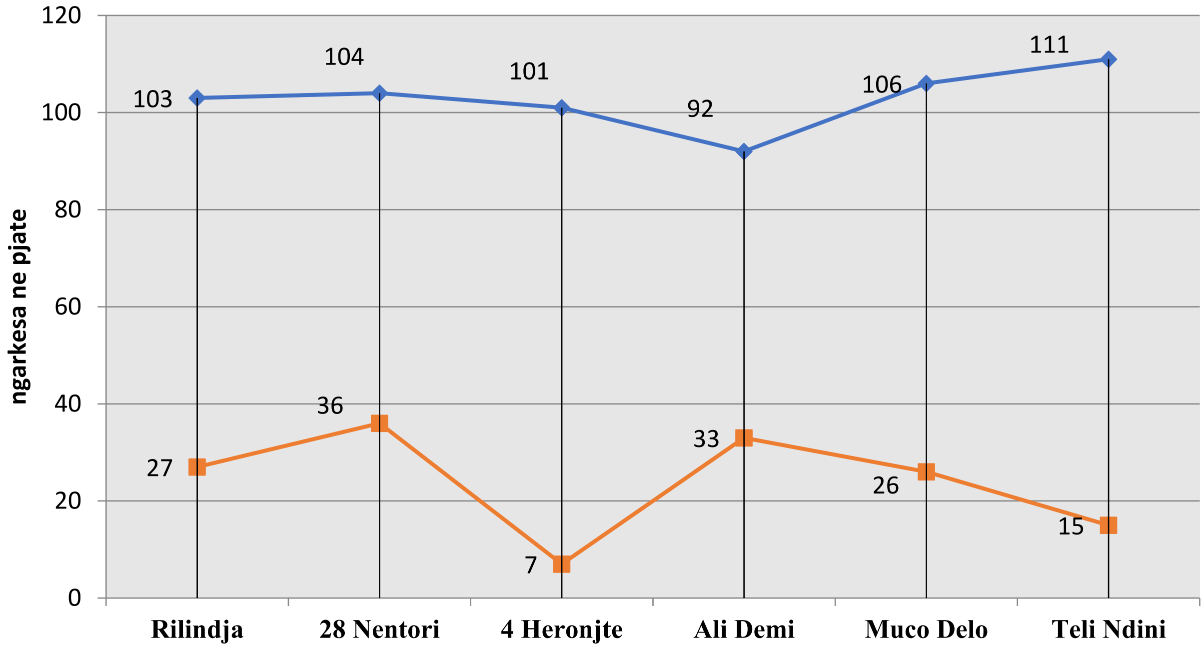

Figure 2. *Graphical representation of the number of microbial loads isolated from schools in Vlorë (average number of microorganisms per Petri dish). *__Blue color:__ load on PCA plates after 48 hours of incubation; *__Orange color__; number of loads on CAPEK plates where fungi have developed.*

Table IV presents the fungal load and relative contribution of fungi to total microbial contamination in five primary schools of Vlorë. The results show substantial variability in fungal presence among the schools.

The highest relative fungal load was observed in *4 Heronjët* school (85.7% of total microbial load), followed by *Muço Delo* (34.6%) and *28 Nëntori* (30.5%). Lower fungal proportions were recorded in *Rilindja* (18.5%), *Ali Demi* (18.6-27.7%), and *Teli Ndini* (13.3%).

Dominant fungal genera included *Mucor*, *Aspergillus*, and *Candida*, which are commonly associated with indoor airborne fungal communities. *Mucor spp.* was the most frequently isolated genus across all schools, while *Aspergillus* species were also consistently present.

Overall, these findings indicate heterogeneous fungal contamination in Vlorë schools, with fungi contributing variably to total microbial air pollution, while bacterial contamination remains predominant in most environments.

Table IV. *Fungal load results in the five primary schools of Vlorë.*

School	Medium	Colonies per Plate	Notes (fungi as % of total microbial load and dominant species)
RILINDJA	CAPEK	27	(5 fungi) 18.5% fungi - *Mucor* spp.
28 NËNTORI	CAPEK	36	(11 fungi) Colonies pigmented red and yellow; 30.5% fungi - *Mucor* spp., *Mucor mucedo*, *Aspergillus terreus*
4 HERONJTË	CAPEK	7	(6 fungi) 85.7% fungi - *Mucor* spp., *Aspergillus terreus*

ALI DEMI	CAPEK-1	23	(9 fungi), average 33 colonies, average 9 fungi; colonies pigmented red and yellow; 27.7% fungi - *Mucor hiemalis*, *Mucor mucedo*, *Aspergillus* spp.
	CAPEK-2	43	(8 fungi) Colonies pigmented red and yellow; 18.6% fungi - *Mucor* spp., *Aspergillus niger*, *Aspergillus terreus*
MUÇO DELO	CAPEK	26	(9 fungi) Colonies pigmented red and yellow; 34.6% fungi - predominantly *Aspergillus terreus* and *Candida* spp.
TELI NDINI	CAPEK	15	(2 fungi) Colonies pigmented yellow and red; 13.3% fungi - *Aspergillus niger*, *Mucor* spp.

Figure 3 illustrates the total microbial loads and fungal loads on CAPEK plates from schools in Vlorë. The graph confirms that bacterial contamination generally exceeds fungal contamination in most schools (blue bars).

Fungal loads (burgundy bars) varied considerably between schools, with the highest contributions observed in *4 Heronjët* and *Muço Delo*, consistent with the data reported in Table IV. Lower fungal presence was observed in *Rilindja* and *Teli Ndini* schools, highlighting heterogeneity in fungal air contamination.

Overall, the figure supports the observation that while bacterial presence predominates, fungal contamination represents a variable but important component of indoor microbial air quality in Vlorë schools.

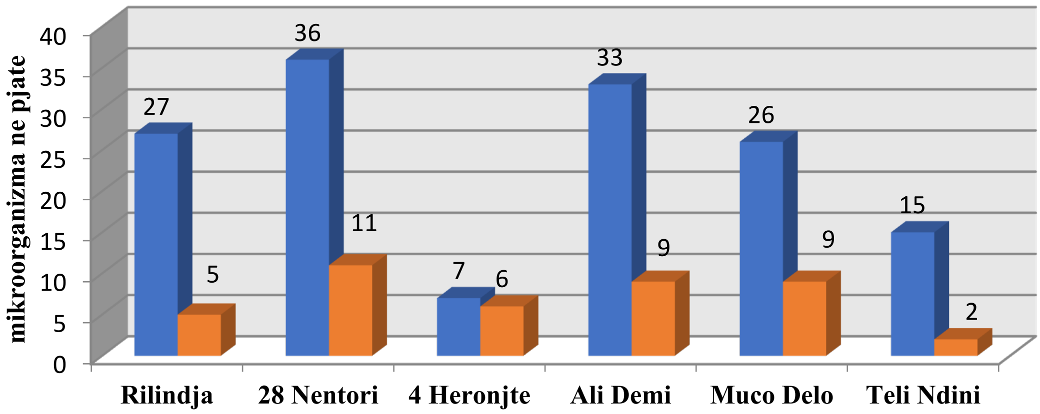

Figure 3. *Total microbial loads on CAPEK (microorganisms per Petri dish) in samples collected from schools in Vlora. *__Blue color__: loads on CAPEK; *__Burgundy color__: fungal loads on CAPEK.*

Figure 4 presents the percentage of fungal loads relative to total microbial loads on CAPEK plates in schools of Vlorë (Group 1). The graph highlights considerable variability in fungal contribution across schools.

The highest fungal proportions were observed in *4 Heronjët* and *Muço Delo* schools, ranging from 30% to 85% of the total microbial load, while Rilindja and Teli Ndini exhibited the lowest fungal proportions (13%-18%).

These results confirm that fungal contamination, although generally lower than bacterial loads, can represent a significant fraction of indoor microbial communities in certain school environments, emphasizing the heterogeneity of indoor air quality.

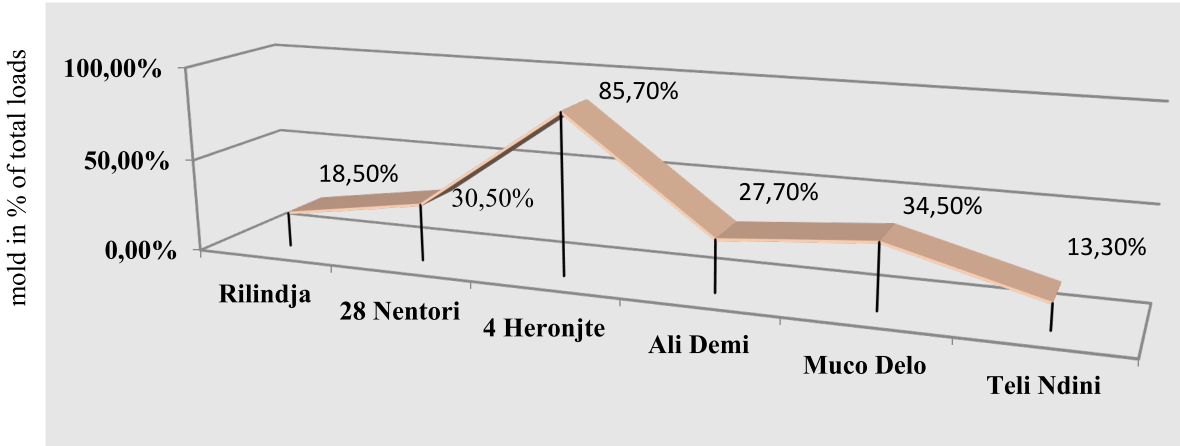

Figure 4. *Percentage of fungal loads in samples collected from schools in Vlorë (Group 1), compared to total loads in CAPEK medium.*

Table V presents the microbial and fungal loads from the second group of schools in Vlorë, including classrooms, corridors, and schoolyards.

Bacterial contamination, assessed on PCA plates, was generally high across all sampled environments, with the highest colony counts observed in corridors and yards (*Pilo Prifti* corridor: 178 colonies; yard: 162 colonies). Classrooms generally had lower bacterial loads than corridors and outdoor areas.

Fungal contamination, assessed on CAPEK plates, showed substantial variability. The highest relative fungal contributions were observed in the *Jani Minga* corridor (85% of total microbial load) and the *Halim Xhelo* corridor (73.5%), while classrooms and yards typically exhibited lower fungal percentages (7.7-33%). Dominant fungal genera included *Aspergillus*, *Mucor*, *Penicillium*, *Cladosporium*, *Rhizopus*, and *Endomycopsis*, reflecting typical indoor and semi-outdoor fungal communities.

Overall, the data indicates heterogeneous distribution of fungal contamination, with corridors showing the highest fungal proportions in several schools, while bacterial loads remained predominant in most indoor and outdoor environments.

Table V. *Results from the second group of schools in the city of Vlorë.*

School	Medium	Colonies per Plate	Notes
HALIM XHELO			
Classroom	PCA	15	Yellow bacilli
Corridor	PCA	67	Red and yellow bacterial and yeast colonies
Yard	PCA	49	Yellow bacilli

Classroom	CAPEK	7 (1 fungal)	14.3% fungi - *Mucor* spp., *Cladosporium*, *Endomycopsis* spp.
Corridor	CAPEK	34 (25 fungal)	73.5% fungi - *Aspergillus* spp.
Yard	CAPEK	55 (11 fungal)	20% fungi - *Aspergillus* spp., *Aspergillus terreus*, *Aspergillus niger*, *Penicillium* spp.
PILO PRIFTI			
Classroom	PCA	143	
Corridor	PCA	-	
Yard	PCA	162	
Classroom	CAPEK	69 (13 fungal)	19% fungi - *Penicillium* spp., *Aspergillus terreus*, *Cladosporium* spp., *Alternaria* spp., pigmented bacteria and yeasts
Corridor	CAPEK	-	
Yard	CAPEK	89 (11 fungal)	12.5% fungi - same genera, *Aspergillus* spp.
JANI MINGA			
Classroom	PCA	-	
Corridor	PCA	178	Yellow bacilli
Yard	PCA	127	Many pigmented bacteria in red and yellow; red yeast *Rhodotorula* spp.
Classroom	CAPEK	-	
Corridor	CAPEK	20 (17 fungal)	85% fungi - *Aspergillus* spp.
Yard	CAPEK	91 (7 fungal)	7.7% fungi - *Mucor* spp., *Penicillium* spp.
ISMAIL QEMALI			
Classroom	PCA	49	Red and yellow colonies
Corridor	PCA	123	Yellow bacilli
Yard	PCA	167	Red and yellow bacterial colonies
Classroom	CAPEK	28 (5 fungal)	18% fungi
Corridor	CAPEK	36 (12 fungal)	33% fungi
Yard	CAPEK	151 (20 fungal)	13% fungi - *Aspergillus* spp., *Rhizopus nigricans*, *Mucor* spp.

Figure 5 shows the total microbial loads on PCA plates in the second group of schools in Vlorë, expressed as the number of microorganisms per Petri dish. The graph shows that bacterial contamination is widespread across all schools and locations (classrooms, corridors, and yards).

The highest bacterial loads were consistently observed in corridors and yards, particularly in *Pilo Prifti* and *Jani Minga* schools, while classrooms generally exhibited lower bacterial counts. The distribution of colonies also reflects the heterogeneity of microbial air contamination within different indoor and semi-outdoor environments.

Overall, Figure 5 confirms that bacterial presence dominates indoor microbial communities in Vlorë schools, with corridors and outdoor areas being more heavily contaminated than classrooms.

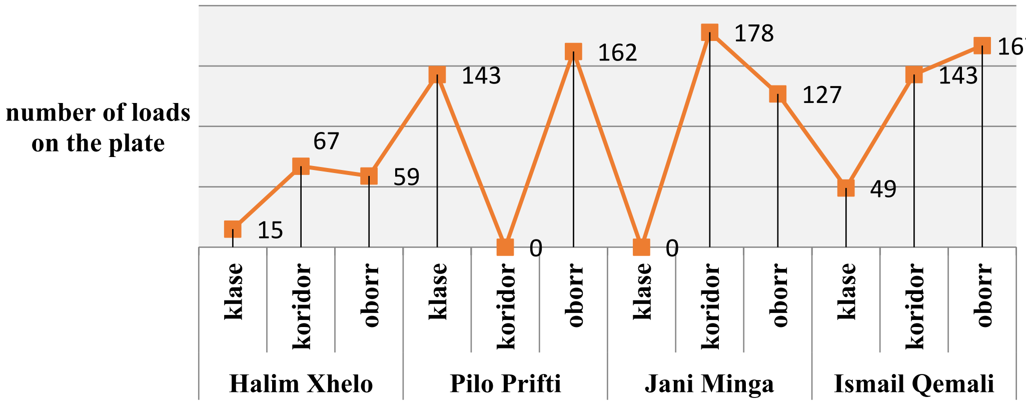

Fig. 5. *Total microbial load (Number of microorganisms per Petri dish) on PCA medium in the second group of schools in Vlora.*

Figure 6 illustrates the total fungal loads on CAPEK plates in the second group of schools in Vlorë, expressed as the number of fungal colonies per Petri dish.

The highest fungal loads were observed in corridors, particularly in *Jani Minga* (17 fungi, 85% of total microbial load) and *Halim Xhelo* (25 fungi, 73.5%), while classrooms and yards generally exhibited lower fungal counts. Fungal distribution is highly heterogeneous across different school environments, reflecting localized environmental conditions and airflow patterns.

Overall, Figure 6 confirms that corridors tend to have the highest fungal load, while classrooms and outdoor areas show lower but still significant fungal loads. Dominant genera include *Aspergillus*, *Mucor*, *Penicillium*, *Cladosporium*, and *Rhizopus*, consistent with typical indoor fungal communities in school settings.

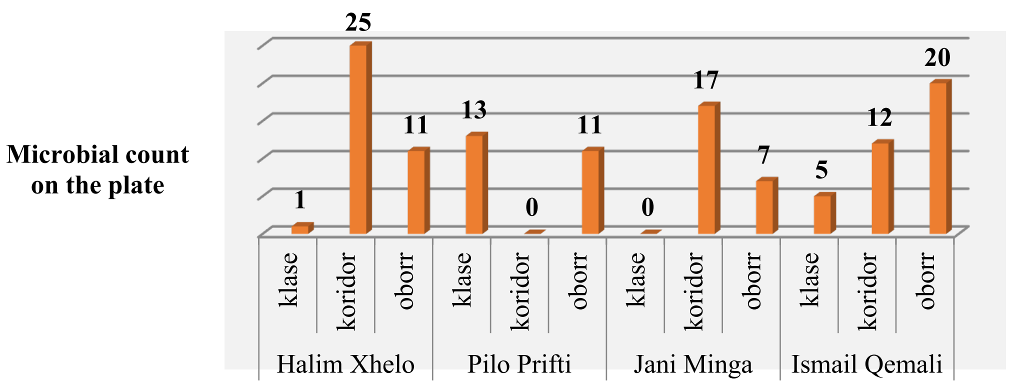

Figure 6. *Total fungal load (Number of fungi per Petri dish) on CAPEK medium in the second group of schools in Vlora.*

Table VI presents microbial and fungal loads from four primary schools in Malësia e Madhe. Bacterial contamination, assessed on MPA plates, was generally highest in corridors (*Preke Gjoni-Bajze*: 141 colonies; *Abdyl Bajraktari-Koplik* courtyard: 136 colonies), while classrooms exhibited lower bacterial loads across most schools. Yards and courtyards showed variable bacterial presence, often influenced by vegetation density.

Fungal contamination, assessed on PDA plates, exhibited marked variability between environments and schools. Corridors in some schools (*Preke Gjoni-Bajze*: 90.9%; *Muhamet Hasmuja-Grizh*: 100%) had the highest fungal proportions relative to total microbial load, whereas classrooms and courtyards displayed lower percentages (6.8-26%). Notably, fungal loads were particularly high in areas with abundant vegetation, such as courtyards, highlighting the influence of local environmental conditions.

Dominant fungal genera included *Aspergillus*, *Mucor*, *Penicillium*, *Trichoderma*, *Cladosporium*, *Rhizopus*, and yeast-like fungi (*Candida*, *Saccharomycopsis*, *Aureobasidium*), reflecting typical indoor and semi-outdoor fungal communities in school environments.

Overall, these results indicate that corridors and vegetated courtyards tend to accumulate the highest fungal loads, while bacterial contamination predominates in classrooms and other indoor environments. The data underscore the heterogeneity of indoor microbial air quality across schools in Malësia e Madhe.

Table VI. *Results from four primary schools in the city of Malësia e Madhe.*

School	Medium	Colonies per Plate	Notes
PREKE GJONI-BAJZE			
Classroom	MPA	83	
Corridor	MPA	141	
Courtyard	MPA	91	
Classroom	PDA	34/8 fungi	23.5% fungi, mostly Mucor spp.
Corridor	PDA	33/30 fungi	90.9% fungi, Aspergillus spp.
Courtyard	PDA	65/65 fungi	100% fungi. Fungal load increased in the courtyard due to abundant vegetation: Aspergillus terreus, Trichoderma viride, Aspergillus niger, Rhizopus nigricans, Penicillium spp.
MUHAMET HASMUJA-GRIZH			
Classroom	MPA	37	
Corridor	MPA	53	
Courtyard	MPA	29	
Classroom	PDA	12/12 fungi	100% fungi: Penicillium crysogenum, Aspergillus rubrum, Basidiomycete - Aureobasidium, Biscogniauxia fulva
Corridor	PDA	17/17 fungi	100% fungi: Candida spp. yeast, Penicillium spp., Aspergillus spp., Saccharomycopsis spp. (yeast-like fungi)

Courtyard	PDA	26/26 fungi	100% fungi. Fungal load increased in the courtyard due to vegetation: Cladosporium spp., Aspergillus spp., Mucor spp., Penicillium spp.
ABDYL BAJRAKTARI-KOPLIK			
Classroom	MPA	48	
Corridor	-	-	
Courtyard	MPA	136	Many bacteria are pigmented red.
Classroom	PDA	15/4 fungi	26% fungi: Aspergillus terreus, Penicillium spp.
Corridor	-	-	
Courtyard	PDA	296/20 fungi	6.8% fungi: Mucor spp., Penicillium spp., Rhizopus nigricans.
KOL MARTINI-DEDAJ			
Classroom	MPA	83	
Corridor	MPA	99	
Courtyard	MPA	67	
Classroom	PDA	53/11 fungi	20.8% fungi
Corridor	PDA	30/15 fungi	50% fungi
Courtyard	PDA	45/8 fungi	17.8% fungi: Aspergillus spp., Rhizopus nigricans, Mucor spp.

Figure 7 presents the total microbial loads on MPA plates in the four primary schools of Malësia e Madhe. The graph shows that bacterial contamination is highest in corridors and courtyards, particularly in *Preke Gjoni-Bajze* corridor (141 colonies) and *Abdyl Bajraktari-Koplik* courtyard (136 colonies). Classrooms consistently exhibited lower bacterial counts across all schools.

These results highlight the heterogeneous distribution of bacterial contamination within school environments, with corridors and outdoor areas acting as the main reservoirs of microbial load.

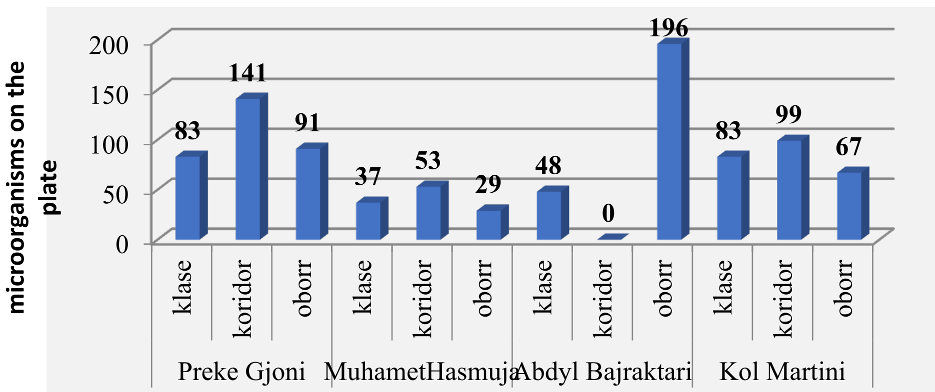

Fig. 7. *Graphical representation of total microbial loads in schools of Malësia e Madhe (MPA medium).*

Figure 8 illustrates the percentage of fungal loads relative to the total microbial load on PDA plates in schools of Shkodër (Malësia e Madhe).

The highest fungal proportions were consistently observed in corridors and courtyards, reaching up to 100% of the microbial load in certain locations (*Muhamet Hasmuja-Grizh* classrooms and courtyards; *Preke Gjoni-Bajze* courtyard). Classrooms generally showed lower fungal percentages (6.8-26%), while outdoor areas with dense vegetation exhibited markedly higher fungal dominance.

Dominant fungal genres included *Aspergillus*, *Mucor*, *Penicillium*, *Rhizopus*, *Cladosporium*, and yeast-like fungi, consistent with common indoor and semi-outdoor school fungal communities.

These results highlight that fungal contamination in schools of Malësia e Madhe is strongly influenced by environmental conditions, with corridors and vegetated areas acting as hotspots for fungal accumulation.

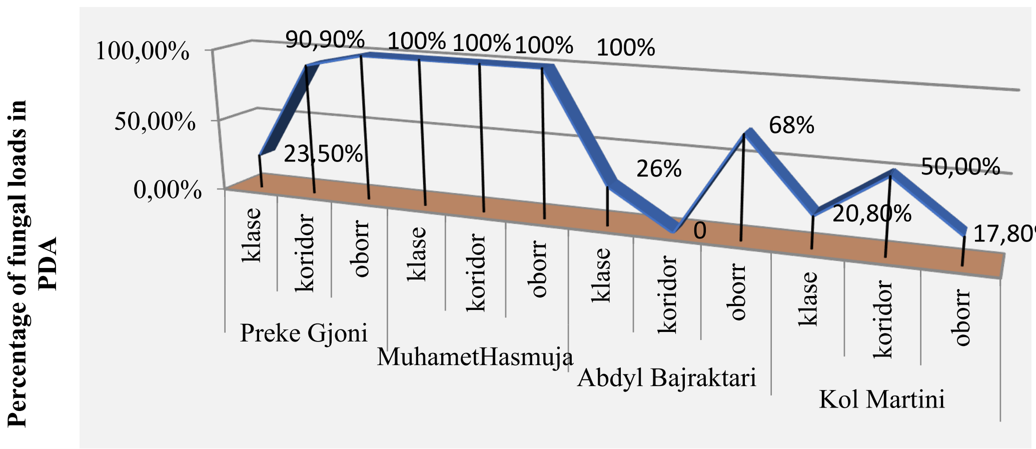

Figure 8. *Presentation of the percentage of fungal loads compared to total loads on PDA medium in schools of Shkodër.*

Table VII presents total microbial and fungal loads in four primary schools of Kukës. Bacterial contamination, assessed on PCA plates, was generally moderate in classrooms (20-58 colonies) and slightly higher in corridors (18-182 colonies). Courtyards showed variable bacterial loads, with *Lidhja e Prizrenit* courtyard reaching 80 colonies. Overall, bacterial contamination was dominated by pigmented colonies and Gram-positive bacilli.

Fungal contamination on CAPEK plates was low across most schools. In *Një Qershori*, the classroom showed 100% fungal load dominated by *Aspergillus spp.*, whereas corridors and courtyards had lower fungal proportions (3.7-18.75%). *Riza Spahiu* and *Bajram Curri* also had minimal fungal presence (0-16.6%), and *Lidhja e Prizrenit* exhibited almost no fungal contamination (0% across all sites).

These findings indicate that fungal contamination in Kukës schools is generally low, particularly compared to other districts, and is mostly confined to classrooms or specific outdoor areas. Bacterial loads are more evenly distributed, with corridors often showing slightly higher counts than classrooms or courtyards.

Table VII. *Results of total microbial and fungal load monitoring in four schools of Kukës.*

School	Medium	Colonies per Plate	Notes
NJË QERSHORI	PCA		
Classroom	PCA	23	Pigmented colonies
Corridor	PCA	34	Pigmented colonies
Courtyard	PCA	-	
Classroom	CAPEK	3/3 fungi	100% fungi, *Aspergillus* spp.
Corridor	CAPEK	108/4 fungi	3.7% fungi, *Aspergillus* spp.
Courtyard	CAPEK	32/6 fungi	18.75% fungi, *Aspergillus* spp., *Aureobasidium* spp.
RIZA SPAHIU	PCA		
Classroom	PCA	58	Yellow and red bacterial colonies
Corridor	PCA	182	Yellow bacterial colonies
Courtyard	PCA	89	Yellow and red bacterial colonies
Classroom	CAPEK	56/3 fungi	5.4% fungi, *Penicillium* spp., *Cladospora* spp.
Corridor	CAPEK	13/0 fungi	0% fungi
Courtyard	CAPEK	54/9 fungi	16.6% fungi, *Alternaria* spp., *Aspergillus* spp., *Mucor* spp.
LIDHJA E PRIZRENIT	PCA		
Classroom	PCA	20	Bacterial colonies - Gram-positive bacilli
Corridor	PCA	35	Bacterial colonies - Gram-positive bacilli
Courtyard	PCA	80	Bacterial colonies - Gram-positive bacilli
Classroom	CAPEK	36/0 fungi	0% fungi
Corridor	CAPEK	35/0 fungi	0% fungi
Courtyard	CAPEK	83/0 fungi	0% fungi
BAJRAM CURRI	PCA		
Classroom	PCA	24	
Corridor	PCA	18	
Courtyard	PCA	-	
Classroom	CAPEK	36/0 fungi	0% fungi
Corridor	CAPEK	43/0 fungi	0% fungi
Courtyard	CAPEK	45/1 fungi	2.2% fungi, *Aspergillus* spp.

Figure 9 illustrates the total bacterial loads on PCA plates in the four primary schools of Kukës. The graph shows that bacterial contamination is generally moderate across classrooms and courtyards, ranging from 20 to 58 colonies per plate in classrooms and 35 to 80 colonies per plate in courtyards. Corridors consistently exhibited slightly higher bacterial loads, peaking at 182 colonies in *Riza Spahiu*.

These results confirm that corridors act as the primary reservoirs of bacterial contamination in Kukës schools, while classrooms and courtyards maintain lower but notable levels of total bacterial load.

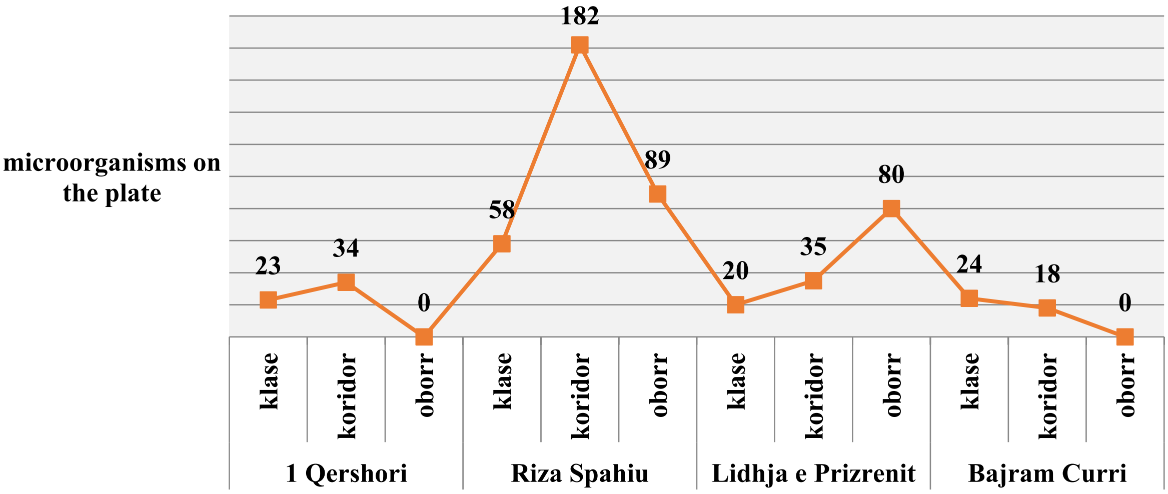

Figure 9. *Total microbial loads on PCA in schools of Kukës.*

Figure 10 presents total microbial loads (burgundy) and fungal loads (blue) on CAPEK plates in the four primary schools of Kukës. Fungal contamination was generally low across all schools. The highest fungal proportion was observed in the classroom of *Një Qershori* (100% of the CAPEK load), while corridors and courtyards in most schools showed minimal fungal presence (0-18.75%). Total microbial loads on CAPEK were higher in corridors compared to classrooms and courtyards, reflecting the combined presence of bacteria, yeasts, and fungi. Overall, these data indicate that in Kukës schools, fungi represent a minor component of indoor microbial contamination, with bacterial and yeast colonies dominating the CAPEK medium in most sites. Environmental factors and school activity patterns likely influence these distributions.

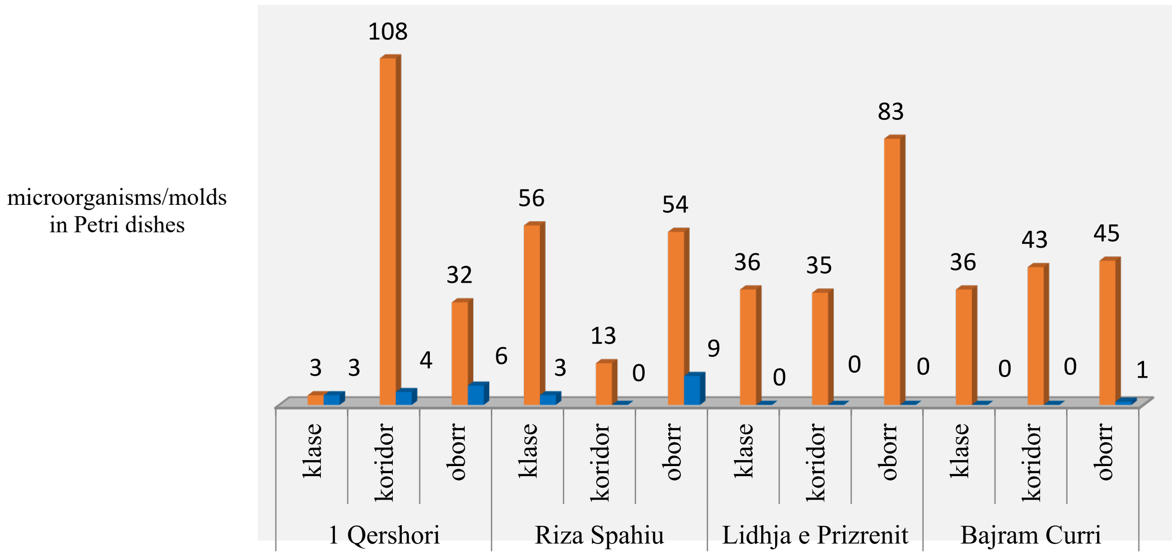

Figure 10. *Total and fungal loads on CAPEK media (orange color - total loads, blue color - fungal loads).*

Figure 11 shows the percentage of fungal loads relative to total microbial loads on CAPEK media in the schools of Kukës.

Fungal contribution to total microbial contamination was generally low across all sampling sites. The highest proportion was observed in the classroom of *Një Qershori* (100%), whereas most corridors and courtyards had minimal fungal presence, ranging between 0% and 18.75%. This confirms that fungi constitute a minor fraction of indoor airborne microorganisms in Kukës schools, with bacteria and yeasts predominating.

These results highlight the variability of fungal distribution within different school environments, with classrooms occasionally showing higher fungal percentages, likely influenced by limited ventilation and localized conditions.

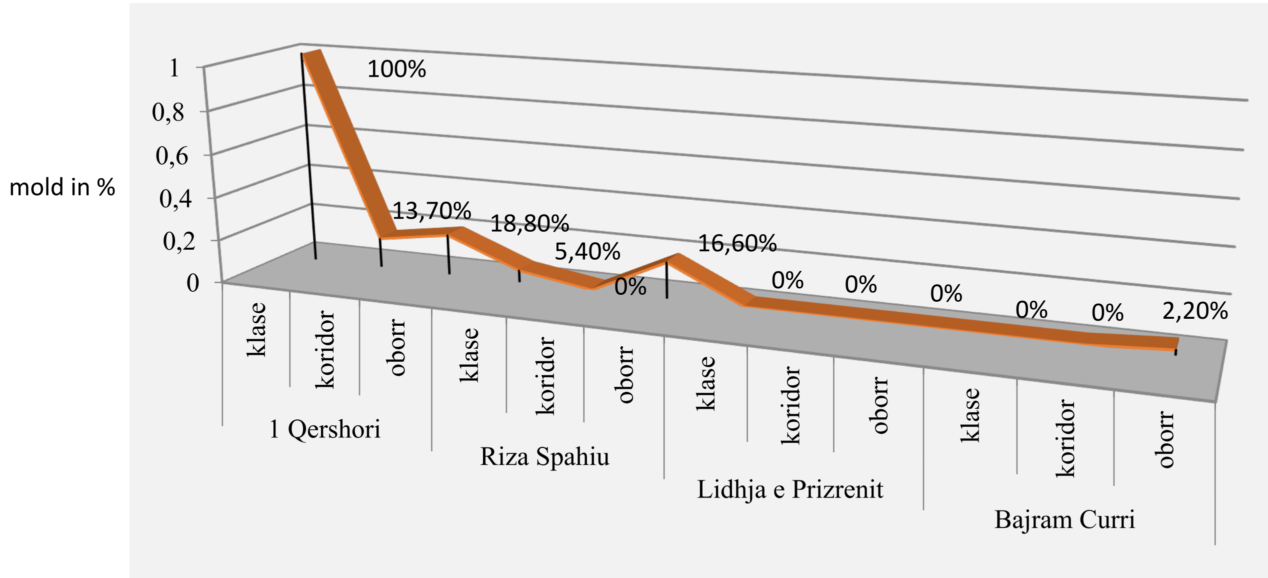

Figure 11. *Percentage of fungal loads relative to total loads on CAPEK media in the schools of Kukës.*

Table VIII presents total microbial and fungal loads in six primary schools of Fier. Overall, bacterial contamination predominated on PCA media across all sampled sites, with corridor colonies ranging from 11 to 145 CFU/plate and courtyard colonies showing similar variability. Pigmented Gram-positive bacilli were the most common bacterial morphotypes.

Fungal loads on CAPEK media were generally lower than bacterial counts. The highest fungal percentages were observed in corridors of *Zylyftar Veleshnja - Velmisht* and *Jorgo Sapiku - Luar* (100% fungi), though the absolute number of fungal colonies remained limited. Most other sites exhibited fungal contributions ranging from 1.37% to 30%, with *Aspergillus spp.*, *Penicillium spp.*, and *Mucor spp.* predominating. Courtyards with more vegetation or macrocolonies occasionally showed elevated fungal presence.

These results indicate that while bacteria dominate airborne contamination in Fier schools, fungi remain a relevant but smaller component, influenced by microenvironmental conditions such as vegetation, air circulation, and surface contamination.

Table VIII. *Monitoring results of total microbial and fungal loads in six schools of the Fier district.*

School	Media	Colonies per Plate	Notes
ZYLYFTAR VELESHNJA - VELMISHT			
Corridor	PCA	47	Pigmented yellow colonies
Courtyard	PCA	36	
Corridor	CAPEK	12/12 fungi	100% fungi: *Aspergillus* spp., *Cladosporium* spp., *Penicillium* spp.
Courtyard	CAPEK	26/1 fungi	3.85% fungi, *Aspergillus* spp.
JORGO SAPIKU - LUAR			
Corridor	PCA	30	Yellow bacterial colonies
Courtyard	PCA	30	Yellow bacterial colonies
Corridor	CAPEK	1/1 fungi	100% fungi - 1 colony *Alternaria* spp.
Courtyard	CAPEK	2/0 fungi	0% fungi
REXHEP KOTHER - KUMAN			
Corridor	PCA	11	Bacterial colonies - Gram-positive bacilli, yellow
Courtyard	PCA	21	Bacterial colonies - Gram-positive bacilli, yellow
Corridor	CAPEK	15/4 fungi	26.7% fungi
Courtyard	CAPEK	12/3 fungi	25% fungi
LEVIZJA DEMOKRATIKE - FIER			
Corridor	PCA	33	Pigmented bacteria colonies - Gram-positive bacilli, yellow
Courtyard	PCA	124	White and pigmented bacterial colonies
Corridor	CAPEK	31/2 fungi	6.45% fungi
Courtyard	CAPEK	73/1 fungi	1.37% fungi - *Aspergillus* spp.
LILI STAVRI - TOPOJE			
Corridor	PCA	145	Pigmented bacteria colonies - Gram-positive bacilli, yellow
Courtyard	PCA	1	Macrocolony of *Bacillus* spp. bacteria covering the plate
Corridor	CAPEK	49/5 fungi	10.2% fungi
Courtyard	CAPEK	121/3 fungi	2.47% fungi

KRISTAQ SHTEMBARI - FIER			
Corridor	PCA	86	Pigmented bacteria colonies - Gram-positive bacilli, yellow
Courtyard	PCA	1	Macrocolony of *Bacillus* spp. bacteria covering the plate
Corridor	CAPEK	15/2 fungi	13.33% fungi
Courtyard	CAPEK	10/3 fungi	30% fungi - *Aspergillus* spp., *Mucor* spp.

Figure 12 illustrates total microbial loads (CFU per Petri dish) on PCA medium in the six schools of Fier. Overall, bacterial contamination was highest in classrooms and corridors of *Lili Stavri - Topoje* and *Kristaq Shtembari - Fier*, reaching up to 145 CFU/plate, while the lowest bacterial loads were observed in *Rexhep Kother - Kuman* corridors (11 CFU/plate).

The data highlight substantial variability in bacterial loads both between schools and between sampling sites (classroom vs. corridor vs. courtyard), likely reflecting differences in occupancy, ventilation, and hygiene practices. Courtyards generally showed lower or moderate microbial loads, except where macrocolonies of *Bacillus spp.* were present.

These results confirm that PCA media primarily captured bacterial populations, with corridors tending to harbor higher counts than classrooms or courtyards, consistent with increased human traffic and accumulation of airborne bacteria.

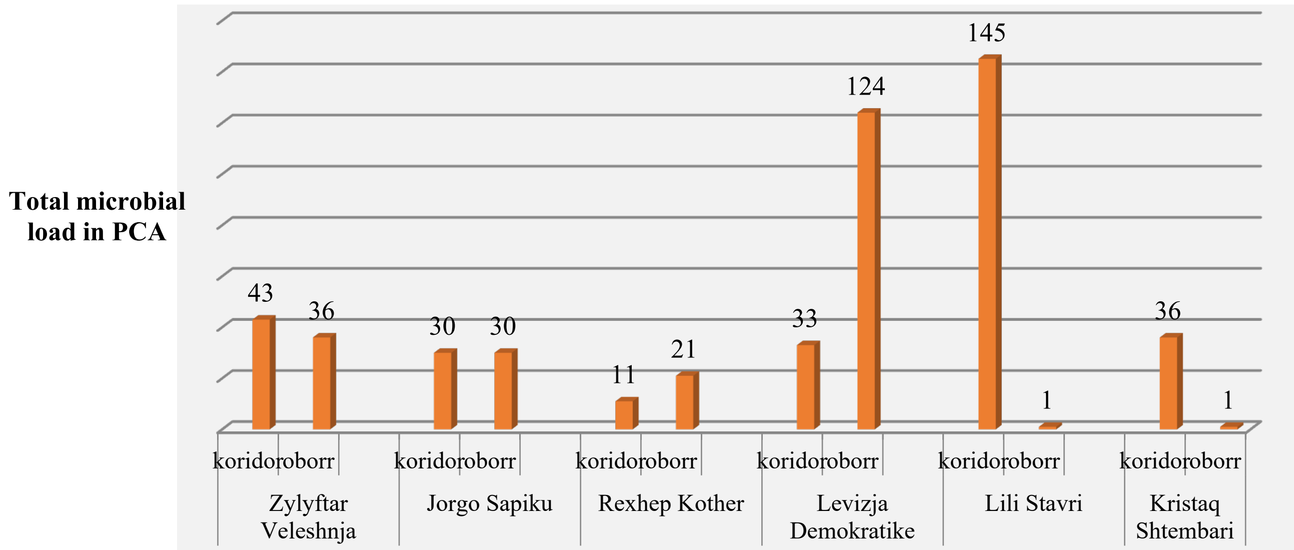

Figure 12. *Total microbial loads on PCA media in the schools of Fier.*

Figure 13 presents the fungal loads (CFU per Petri dish) on CAPEK medium in six schools of Fier. Fungal contamination was generally lower than total bacterial loads observed on PCA, ranging from 1 to 12 CFU/plate. The highest fungal proportions were detected in *Zylyftar Veleshnja - Velmisht* corridors (12 CFU, 100% fungi) and *Kristaq Shtembari - Fier* courtyards (3 CFU, 30% fungi).

Predominant fungal genera included *Aspergillus spp.*, *Cladosporium spp.*, *Penicillium spp.*, and *Mucor spp.*, consistent with typical indoor fungal communities in school environments. Classrooms and corridors exhibited moderate fungal contamination, whereas courtyards with surrounding vegetation occasionally showed higher fungal presence.

These results highlight that fungi constitute a smaller fraction of total microbial load but are widely distributed across different school areas, underlining the need for monitoring and preventive measures to reduce airborne fungal exposure among students.

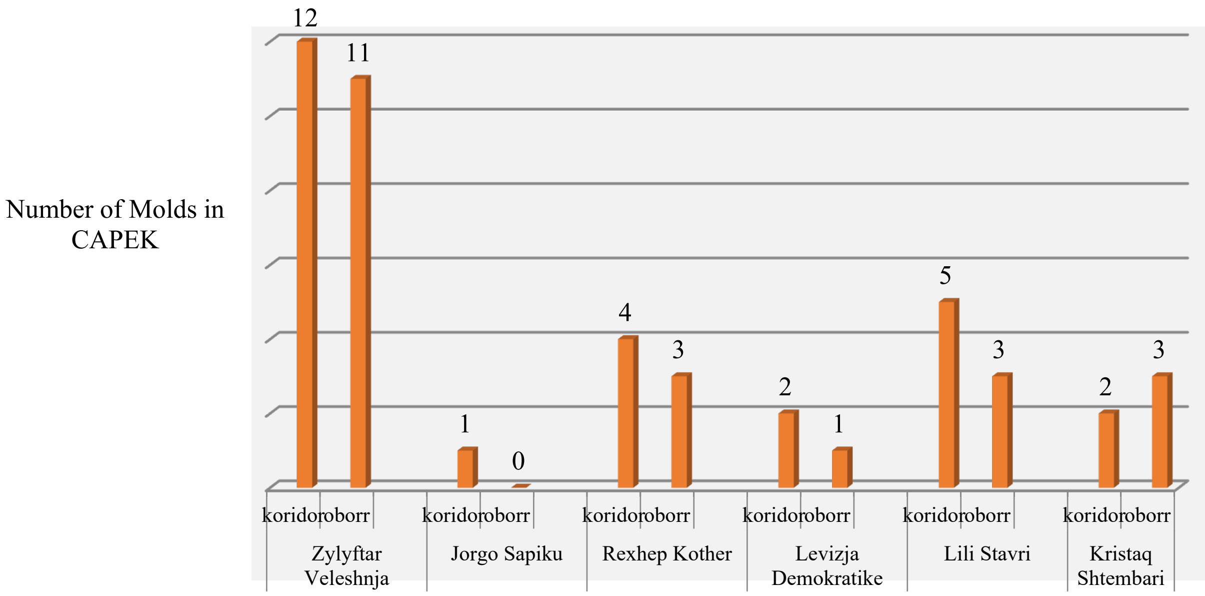

Figure 13. *Fungal loads on CAPEK media in the schools of Fier.*

Risk of Bias

All schools were sampled using standardized methods and culture media, and microbial identification followed established criteria, indicating a low risk of bias.

DISCUSSION

The present study evaluated microbial and fungal contamination in indoor and outdoor environments of primary schools across five Albanian districts, revealing significant variation in both bacterial and fungal loads. Overall, PCA and CAPEK plates indicated that classrooms and corridors consistently harbored higher microbial counts than schoolyards, confirming the trend reported in similar studies and highlighting the accumulation of airborne microorganisms in confined educational spaces (19, 20). Fungal contamination, expressed as a percentage of total microbial load, varied markedly between districts and even among schools within the same city, suggesting a strong influence of local environmental and microclimatic factors on fungal proliferation (21).

In Korçë, fungal loads were moderate, with Aspergillus spp. and Penicillium spp. dominating CAPEK cultures, representing 12-42% of the total microbial load. This aligns with observations by Juntunen et al. (21), who found that indoor fungal diversity in schools correlated with ventilation and cleaning practices. Similarly, in Vlorë, high fungal percentages in certain schools (up to 85%) coincided with poor ventilation or dense vegetation near courtyards, reinforcing findings from Honan et al. (19) that outdoor landscaping and indoor microenvironments influence fungal aerosol deposition. These results underscore the importance of targeted environmental management, including the positioning of classroom furniture, regular cleaning, and humidity control, in limiting fungal exposure (20, 22).

Schools in Malësi e Madhe demonstrated a distinctive pattern: while total bacterial loads on MPA plates were high in corridors and courtyards, fungal dominance reached 100% in several PDA samples, particularly where vegetation and organic debris were abundant. This corroborates studies reporting that outdoor sources, including soil and plant materials, substantially contribute to indoor fungal contamination, particularly in naturally ventilated schools (23, 24). In Kukës, fungal loads were comparatively low, rarely exceeding 20% of total CAPEK counts, suggesting that differences in climate and school infrastructure, such as building age, ventilation systems, and occupancy rates, are critical determinants of microbial air quality (25).

Fier schools exhibited variable patterns, with PCA counts ranging from 11 to 145 colonies per plate and CAPEK fungal proportions from 1% to 100%. The highest fungal loads were observed in courtyards with high vegetation density, a pattern similar to that observed in other Mediterranean regions, where plant-associated fungi contribute substantially to indoor fungal diversity (26). Collectively, these results indicate that microbial and fungal contamination in primary schools is highly context-dependent, influenced by local climate, building design, occupancy, and proximity to outdoor sources.

The combination of active and passive sampling used in this study allowed a comprehensive assessment of airborne microorganisms, demonstrating that simple passive methods may underestimate total fungal exposure, particularly in environments with sporadically distributed fungal aerosols (19, 21). The data emphasize the need for routine monitoring of microbial air quality in schools, given the potential health implications for children, including respiratory irritation, allergic sensitization, and absenteeism (20, 22, 26).

In conclusion, this study provides a detailed cross-sectional evaluation of microbial contamination in Albanian primary schools, highlighting significant heterogeneity between districts and environments. Effective interventions, including improved ventilation, strategic classroom design, vegetation management, and regular cleaning protocols, are essential to minimize exposure to airborne bacteria and fungi and protect schoolchildren's health. The findings contribute to the growing body of evidence that school-specific environmental factors must be considered when assessing and managing indoor air quality (19-26).

CONCLUSIONS

The results of this study demonstrate that primary school environments in Albania exhibit variable microbial loads, with higher bacterial concentrations on PCA/MPA media and fungal concentrations predominantly on CAPEK/PDA media. Indoor areas, such as classrooms and corridors, generally showed elevated bacterial levels compared to outdoor schoolyards, whereas fungal loads were more heterogeneous, often influenced by factors such as ventilation, humidity, and vegetation. Certain schools showed exceptionally high fungal levels, suggesting potential hotspots for airborne fungal exposure. The diversity of isolated fungi, including *Aspergillus*, *Mucor*, *Penicillium*, and *Rhizopus* species, reflects the complexity of indoor bioaerosols in school settings. These findings underscore the need for targeted environmental monitoring and management strategies to reduce microbial exposure, ensure adequate ventilation, and maintain healthy indoor air quality for children. Overall, the study highlights the critical role of school environmental conditions in shaping microbial air quality and provides a basis for preventive interventions in primary educational institutions.

REFERENCES

1. Fang Z, Ouyang Z, Hu L, Wang X, Zheng H, Lin X. Culturable airborne bacteria in outdoor environments in Beijing, China. Microbial Ecology. 2007;54(3):487-496. doi: 10.1007/s00248-007-9216-3
2. Mendell MJ, Mirer AG, Cheung K, Tong M, Douwes J. Respiratory and allergic health effects of dampness, mold, and dampness-related agents. Environmental Health Perspectives. 2011;119(6):748-756. doi: 10.1289/ehp.1002410
3. WHO. WHO guidelines for indoor air quality : dampness and mould. www.who.int. Published January 1, 2009. https://www.who.int/publications/i/item/9789289041683
4. Huttunen K, Rintala H, Hirvonen MR, Vepsäläinen A, Hyvärinen A, Meklin T, Nevalainen A. Indoor air particles and bioaerosols before and after renovation of moisture-damaged buildings. Environmental Research. 2014;129:23-29.
5. Kanchongkittiphon W, Mendell MJ, Gaffin JM, Wang G, Phipatanakul W. Indoor environmental exposures and exacerbation of asthma. Pediatrics. 2015;136(2):e447-e460.
6. Madureira J, Paciência I, Rufo J, et al. Indoor air quality in schools and its relationship with children's respiratory symptoms. Atmospheric Environment. 2020;236:117626.
7. Cabo Verde S, Almeida SM, Matos J, et al. Microbiological assessment of indoor air quality in schools. Building and Environment. 2021;190:107537.
8. Mainka A, Zajusz-Zubek E. Indoor air quality in schools and health effects in children. Environmental Science and Pollution Research. 2022;29:12345-12360.
9. Rim KT, Lim CH. Biological monitoring of fungi and mold exposure. Journal of Occupational Health. 2013;55(5):347-357.
10. Douwes J, Thorne P, Pearce N, Heederik D. Bioaerosol health effects and exposure assessment. Annals of Occupational Hygiene. 2020;64(7):751-767.
11. Llewellyn JW. Indoor air quality sampling methodologies, 1st edition: By K Hess-Kosa. (Pp 300; pound59.99). 2001. Boca Raton, FL, USA: Lewis Publishers, CRC Press. ISBN 1-56670-539-8. Occupational and Environmental Medicine. 2002;59(3):203-203. doi:10.1136/oem.59.3.203
12. Zhang Y, Mo J, Li Y, et al. Impact of COVID-19 prevention measures on indoor air quality in schools. Building and Environment. 2022;219:109189.
13. Liu Z, Li R, Wu Y, Ju R, Gao N. Numerical study on the effect of ventilation on indoor airborne transmission. Building and Environment. 2021;188:107468.
14. Khalil H, Al-Khalidi F, Farah W. Influence of ventilation and occupancy on airborne bacterial contamination in school environments. Indoor Air. 2021;31(6):1734-1745.
15. Li Y, Chen Q, Wang J. Seasonal variation and human impact on bacterial and fungal loads in classroom air. Journal of Environmental Health. 2022;84(4):220-233.
16. Eduard W. Fungal spores: a critical review of the toxicological and epidemiological evidence as a basis for occupational exposure limit setting. Critical Reviews in Toxicology. 2006;36(6-7):449-488. doi: 10.3109/10408440903307333
17. Buonanno G, Fuoco FC, Morawska L, Stabile L. Airborne particle concentrations at schools measured at different spatial scales. Atmospheric Environment. 2013;67:38-45. doi:10.1016/j.atmosenv.2012.10.048
18. Wang R, Zhang L, Liu H. Geographical and climatic determinants of indoor air fungal communities in primary schools. Science of the Total Environment. 2024;856:159061.
19. Honan D, Gallagher J, Garvey J, Littlewood J. Indoor air quality in naturally ventilated primary schools: a systematic review of the assessment & impacts of CO_2 levels. Buildings. 2024;14(12):4003. doi:10.3390/buildings14124003.
20. Badyda A, Muszyński A, Affek K, Doskocz N, Kępa P, Mucha D, Piórkowska A, Rogulski M, Załęska-Radziwiłł M. Schools and Indoor Air Quality: seasonal variation, European Journal of Public Health, Volume 34, Issue S3, November 2024, ckae144.797, doi:10.1093/eurpub/ckae144.797

21. Juntunen M, Täubel M, Yli-Tuomi T, et al. Associations of air cleaning interventions in primary school classrooms with indoor environmental quality and perceived symptoms. Build Environ. 2025;278:112980. doi:10.1016/j.buildenv.2025.112980.
22. Dosumu AA, Colbeck I. Assessment of indoor air quality in a primary school. Discover Environment. 2025;3(1). doi:10.1007/s44274-025-00479-1
23. Cervantes R, Pena P, Riesenberger B, et al. Critical insights on fungal contamination in schools: a comprehensive review of assessment methods. Front Public Health. 2025;13:1557506. doi:10.3389/fpubh.2025.1557506
24. Lazzara V, Stanisci I, Malizia V, Alfano P, La Grutta S. A scoping review of review on school indoor air quality and respiratory health in schoolchildren: Evidence available, key concepts and knowledge gaps. Indoor and Built Environment. Published online December 19, 2025. doi:10.1177/1420326x251403351
25. El-Gendy S, Awad AH, Saeed Y, Kamal S. Indoor air quality of academia-related environments based on microbial and chemical pollutants. Trakya Univ J Nat Sci. 2025;26(2):156-173.
26. Yusof, S.K., Abdull, N., Suhaimi, N.S. et al. Bioaerosol concentration and health implication for children in daycare centers. Aerobiologia 41, 643–665 (2025). doi:10.1007/s10453-025-09872-y