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Pilot Study

Assessment of Hygienic-Sanitary Indicators and Microbiological Exposure in Indoor Environments of Primary Schools in Albania

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ABSTRACT

This pilot study aimed to evaluate hygienic–sanitary conditions and microbiological contamination in indoor environments of primary schools in Albania. Fifty primary schools enrolling 9-year-old students were randomly selected from six districts in Albania. Hygienic–sanitary and infrastructural conditions were assessed using five standardized survey instruments. Air and surface samples were collected and analyzed for bacterial, fungal, and yeast contamination. Environmental parameters, including temperature, relative humidity, and ventilation efficiency, were systematically monitored. A substantial proportion of schools did not comply with recommended hygiene and ventilation standards, particularly in restrooms and common indoor areas. Potentially pathogenic microorganisms were predominantly detected in environments with elevated humidity and inadequate cleaning practices. The study reveals significant deficiencies in indoor environmental quality in Albanian primary schools and highlights the need for infrastructural improvements and the implementation of sustainable hygiene and environmental monitoring protocols to reduce microbiological risks and protect children's health.

INTRODUCTION

School environments play a fundamental role in safeguarding and promoting children's health, as pupils spend a significant proportion of their daily lives in indoor educational settings. Indoor air quality (IAQ) and hygienic–sanitary conditions in schools are widely recognized as critical determinants of respiratory health, infection control, cognitive performance, and overall well-being among children (1, 2). Inadequate ventilation, elevated humidity, and insufficient sanitation practices contribute to the accumulation and spread of biological contaminants, including bacteria, fungi, and yeasts, thereby increasing the risk of communicable and non-communicable diseases.

A growing body of scientific evidence demonstrates that poor indoor environmental quality in schools is associated with an increased prevalence of asthma symptoms, allergic conditions, respiratory infections, and school absenteeism (3, 4). Children are particularly susceptible to indoor environmental hazards due to their developing respiratory and immune systems, higher inhalation rates relative to body weight, and close contact in classroom settings (5). Consequently, international health authorities emphasize the importance of maintaining appropriate ventilation rates, temperature control, relative humidity levels, and effective cleaning protocols in educational facilities (6, 7).

Building design, maintenance practices, occupancy density, and environmental parameters, such as temperature and humidity, strongly influence microbiological contamination of indoor air and surfaces. Studies conducted in school settings have shown that dampness, inadequate ventilation, and poor hygiene practices significantly increase microbial loads, particularly in restrooms and enclosed indoor spaces (8, 9). These conditions not only facilitate microbial growth but also enhance the persistence of potentially pathogenic microorganisms, posing a direct threat to children's health.

Despite extensive research in high-income countries, evidence regarding indoor air quality and hygienic–sanitary conditions in schools in low- and middle-income countries remains limited. In Albania, data on microbiological contamination and environmental health indicators in school settings are scarce, and routine monitoring systems are not systematically implemented. Existing regulations mainly address structural and safety requirements, with limited focus on indoor environmental quality and microbiological risk assessment. This pilot study aimed to evaluate hygienic–sanitary indicators and microbiological contamination in indoor environments of primary schools in Albania, while simultaneously assessing key environmental parameters, including temperature, relative humidity, and ventilation efficiency. By generating baseline evidence, this study seeks to support the development of targeted public health interventions and strengthen environmental health monitoring policies in school settings.

MATERIALS AND METHODS

Study Design and Study Area

A cross-sectional observational study was conducted in 50 primary schools across six districts in Albania, representing urban, suburban, and rural settings. Schools enrolling 9-year-old students were randomly selected to ensure a representative sample of structural conditions, hygienic–sanitary practices, and environmental characteristics. The study aimed to assess indoor environmental quality, hygiene indicators, and microbiological contamination in school settings.

Eligibility Criteria

Public primary schools operating during the study period and granting access for environmental and microbiological assessments were included. Schools undergoing major renovation or with restricted access were excluded.

Data Collection

Data were collected using standardized tools:

- Structured interviews with school administrators regarding maintenance, repairs, and sanitation policies;
- Building inspection checklists to evaluate structural integrity, heating systems, ventilation, and evidence of water damage;
- Assessment of visible mold, dampness, and wall or ceiling damage;
- Restroom hygiene inspections, including plumbing conditions, temperature adequacy, privacy, and cleanliness;
- Classroom and common area evaluations, including environmental parameters, occupancy, and potential pollution sources.

Microbiological Sampling

Air and surface samples were collected in classrooms, restrooms, and common indoor areas using standardized protocols. Microbial identification included:

- Bacterial colonies (pigmented and non-pigmented);
- Fungal species (e.g., *Candida spp., Alternaria spp., Aspergillus spp., Mucor spp.*);
- Yeasts and other opportunistic microorganisms.

Environmental parameters, including temperature, relative humidity, and ventilation efficiency, were systematically recorded at each sampling site.

Quantification and Analysis

Microbial loads were expressed as colony-forming units per cubic meter of air (CFU/m^3) or per surface area (CFU/cm^2). Descriptive statistics were used to summarize structural, hygienic, and environmental conditions. Comparative analyses were conducted between urban and rural schools, and associations between environmental factors, hygiene indicators, and microbial contamination were assessed using chi-square tests, Fisher's exact tests, and ANOVA, as appropriate. A p-value < 0.05 was considered statistically significant. Multivariate analyses (Pillai's Trace, Wilks' Lambda, and Hotelling's Trace) were applied to identify variables significantly influencing microbial loads.

Risk of Bias

Sampling procedures, culture conditions, and identification protocols were standardized across all schools. All samples were collected under similar operational conditions to minimize potential bias.

RESULTS

The majority of schools included in the assessment were public (98%) and provided general education (94%). Most schools consisted of a single building housing all classrooms (98%), with minimal representation of boarding and special schools. These findings indicate a relatively homogeneous school infrastructure, predominantly composed of public general education institutions with single-building layouts (Table I).

Table I. *Structural and managerial characteristics of the schools included in the assessment.*

School management	**Frequency**	**Percentage**
Public	49	98.0
Private	0	0.0
Not applicable	1	2.0
Total	50	100.0
School type	**Frequency**	**Percentage**
General education school	47	94.0
Boarding school	1	2.0
Special school	1	2.0
Not applicable	1	2.0
Total	50	100.0
Number of buildings with classrooms in schools	**Frequency**	**Percentage**
1 building	49	98.0
2 buildings	0	0.0
3 or more buildings	0	0.0
Not applicable	1	2.0
Total	50	100.0

Environmental factors within schools were influenced by both structural conditions and maintenance history. Water leakage or flooding during the past 12 months was significantly associated with recent major repairs or renovations (p = 0.023), suggesting that schools undergoing repairs were more likely to have experienced water-related issues.

The presence of mold in school buildings varied according to the type of heating system (p = 0.032). Schools relying on stoves or individual classroom heaters showed a higher prevalence of mold, whereas buildings with central or comprehensive heating systems exhibited lower or no mold detection. These findings highlight the importance of adequate building maintenance and effective heating systems in reducing indoor environmental hazards (Table II).

Table II. *School infrastructure conditions and their impact on environmental factors.*

		Presence of water leakage or flooding in the last 12 months			Total	P-value
		Yes	No	Not Applicable		
Major repairs or renovations within the last 5 years	No	11	11	0	22	
	Yes, within the past year	1	8	0	9	.023
	Yes, from 1 to 5 years ago	3	16	0	19	
	Total	15	35	0	50	
		Presence of mold growth inside the building			**Total**	**P-value**
		Yes	No	Not Applicable		
Heating systems	No heating system	1	1	0	2	.032
	Central heating system	1	3	1	5	
	School heating system for the entire building	3	15	0	18	
	Stoves or internal heaters in individual rooms	10	13	0	23	
	Not applicable	2	0	0	2	
	Total	17	32	1	50	

Restroom conditions in the assessed schools were generally adequate, although some deficiencies were observed. Pipe or toilet leaks were reported in 26% of schools, while 58% of restrooms maintained suitable temperatures. All restrooms were equipped with partitions ensuring privacy, and 90% of toilets had doors that could be locked from the inside. Accessibility for cleaning was high, with 98% of toilets reported as easy to clean.

In contrast, outdoor toilet facilities were poorly equipped: only 10% had accessible paths usable throughout the year, and only 6% had functional lighting along the paths. These findings indicate that, while indoor restroom infrastructure largely supports hygiene and privacy, outdoor facilities require substantial improvement to ensure safe and hygienic access for students year-round (Table III).

Table III. *Condition and status of school restrooms.*

Presence of leaks from pipes or toilets	**Frequency**	**Percentage**
Yes	13	26.0
No	37	74.0
Total	50	100.0
Presence of suitable temperatures in the toilet area	**Frequency**	**Percentage**
Yes	29	58.0
No	20	40.0
Not applicable	1	2.0
Total	50	100.0
The existence of a partition between toilets that provide privacy and those that do not guarantee it	**Frequency**	**Percentage**

Yes	50	100.0
No	0	0.0
Total	50	100.0
If toilets have doors, they can be locked from the inside to ensure user privacy.	**Frequency**	**Percentage**
Yes	45	90.0
No	4	8.0
Not applicable	1	2.0
Total	50	100.0
Easy toilet cleaning	**Frequency**	**Percentage**
Yes	**49**	**98.0**
No	0	0.0
Not applicable	1	2.0
Total	50	100.0
For outdoor toilets, the existence of a path to the toilet that can be easily used in any season	**Frequency**	**Percentage**
Yes	5	10.0
No	7	14.0
Not applicable	38	76.0
Total	50	100.0
For outdoor toilets, the lights work properly on the way to the toilet.	**Frequency**	**Percentage**
Yes	3	6.0
No	9	18.0
Not applicable	38	76.0
Total	50	100.0

The majority of schools (58.8%) were located in urban areas, with 25.5% situated in rural settings and a smaller proportion in densely populated city areas (9.8%) or suburban zones (3.9%).

Potential nearby sources of air pollution were generally limited. Approximately one-third of schools had a car parking area (32%) or other minor pollution sources (32%) within 100 meters. Busy roads or railways were present near 24% of schools. No schools reported nearby power plants, fuel dispensing stations, or major industries within a 3 km radius.

These findings suggest that, while most schools are located in urban environments, exposure to significant local air pollution sources is relatively low. Nevertheless, localized traffic-related emissions may still impact indoor air quality (Table IV).

Table IV. *Distribution of school building locations and potential nearby sources of air pollution in the studied areas.*

Location of the school building	**Frequency**	**Percentage**	
Urban area	30	58.8	
Densely populated area in the city	5	9.8	
Suburban area	2	3.9	
Rural area	13	25.5	
Total	50	98.0	
Possible nearby sources of air pollution and nature	**Frequency/Percentage**		
	Yes	No	Missing

Car parking within 100 m	16 (32.0)	28 (56.0)	6 (12.0)
Attached garage	3 (6.0)	41 (82.0)	6 (12.0)
Busy road or railway (at least part of the day) within 100 m	12 (24.0)	32 (64.0)	6 (12.0)
Power plant for the building	0 (0.0)	44 (88.0)	6 (12.0)
Gasoline pumps or other fuel dispensing equipment within 100 m	0 (0.0)	44 (88.0)	6 (12.0)
Major industry or power plants within 3 km	0 (0.0)	44 (88.0)	6 (12.0)
Other	16 (32.0)	28 (56.0)	6 (12.0)

The presence of mold (*Alternaria*) and yeast (*Candida spp.*) in school environments was strongly associated with elevated surface moisture levels. *Alternaria* was detected exclusively on wet surfaces ($p < 0.001$), whereas *Candida spp.* was found only in two locations where surface moisture was recorded ($p = 0.001$). No microbial growth was observed on dry surfaces.

These findings underscore the critical role of moisture in promoting fungal and yeast contamination in school buildings. Effective control of dampness and water infiltration is therefore essential to minimize the risk of microbiological proliferation and to protect children's health (Table V).

Table V. *Association between mold presence (Alternaria and Candida spp.) and moisture levels as measured by surface detector.*

		The degree of moisture in the visible areas of mold according to the surface moisture detector					**Total**	**P-value**
		The surface is dry	Damp surface	Wet surface	Not measured	Not applicable		
Alternaria	Yes	0	0	1	0	0	1	.000
	No	28	8	1	7	5	49	
	Total	28	8	2	7	5	50	
Candida spp	Yes	0	0	0	0	2	2	
	No	28	8	2	7	3	48	.001
	Total	28	8	2	7	5	50	

Moisture-induced damage to building materials was significantly associated with the presence of microorganisms. White-pigmented bacterial colonies were more frequently detected in areas where damage was observed in three or more locations within a room ($p = 0.027$). The presence of Candida spp. was also associated with material damage ($p = 0.005$), whereas Alternaria spp. was detected primarily in areas showing minor or localized damage ($p = 0.027$).

These results indicate that structural deterioration caused by water infiltration or persistent humidity provides a favorable environment for microbial growth. Maintaining the integrity of building materials and promptly repairing water-related damage are, therefore, crucial measures to limit microbial proliferation and to ensure a healthier indoor environment for students (Table VI).

Table VI. *Association between moisture-induced damage to building materials and the presence of microorganisms (pigmented white bacteria, Candida spp., and Alternaria spp.).*

		Damage to building materials due to water/humidity					
		No damage to sensitive building materials	Noticeable damage in one or two places in the room/space	Damage observed in three or more places in the room/space	Not applicable	**Total**	**P-value**
White pigmented bacterial colonies	Yes	1	0	2	0	3	
	No	30	6	4	7	47	.027
	Total	31	6	6	7	50	
Candida spp	Yes	0	0	0	2	2	
	No	31	6	6	5	48	.005
	Total	31	6	6	7	50	
Alternaria spp	Yes	1	2	0	0	3	
	No	30	4	6	7	47	.027
	Total	31	6	6	7	50	

The presence of indoor flush toilets was significantly associated with the detection of microorganisms. Fungi imperfecti were identified in five schools with flush toilets (p = 0.002), whereas yellow-pigmented bacterial colonies were detected in seven schools with flush toilets (p = 0.012). No microorganisms of these types were found in schools lacking indoor flush toilets.

These findings suggest that indoor sanitation facilities, while essential for maintaining hygiene, may serve as localized reservoirs for microbial growth if not properly maintained. Regular cleaning, adequate ventilation, and moisture control in toilet areas are therefore critical to minimize microbial proliferation and to protect students' health (Table VII).

Table VII. *Association between the presence of indoor flush toilets and the identification of microorganisms in school environments.*

		A toilet with water inside the school building			**Total**	**P-value**
		Yes	No	Not applicable		
Fungi imperfects	Yes	4	0	1	5	
	No	45	0	0	45	.002
	Total	49	0	1	50	
Yellow-pigmented colonies	Yes	6	0	1	7	
	No	43	0	0	43	.012
	Total	49	0	1	50	

The presence of insects in school toilets was significantly associated with the occurrence of various microorganisms. Yellow-pigmented bacterial colonies were detected in both schools with and without insects, but their prevalence was significantly higher in schools where insects were observed (p = 0.002). *Mucor spp.*

was found in 20 instances, primarily in toilets with insects ($p = 0.010$). Other microbial types, including pigmented colonies, red-pigmented bacterial colonies, and *Aureobasidium spp*., were also significantly associated with the presence of insects ($p \leq 0.010$).

These results indicate that insects may act as vectors for microbial dissemination within restroom environments. Effective pest control, combined with proper cleaning and moisture management, is therefore essential to reduce microbial contamination and to protect students' health (Table VIII).

Table VIII. *Association between the presence of insects in school toilets and the identification of various microorganisms in school environments.*

		Presence of insects in the toilet			**Total**	**P-value**
		Yes	No	Not applicable		
Yellow pigmented colonies	Yes	3	3	1	7	
	No	2	40	1	43	.002
	Total	5	43	2	50	
Pigmented colonies	Yes	0	0	1	1	
	No	5	43	1	49	.000
	Total	5	43	2	50	
Red pigmented bacterial colonies	Yes	1	0	0	1	
	No	4	43	2	49	.010
	Total	5	43	2	50	
Mucor spp	Yes	5	15	0	20	
	No	0	28	2	30	.010
	Total	5	43	2	50	
Aureo basidium spp.	Yes	0	0	1	1	
	No	5	43	1	49	.000
	Total	5	43	2	50	

Temperature adequacy in toilet areas was significantly associated with the presence of microorganisms. Both pigmented bacterial colonies and *Aureobasidium spp*. were detected only in locations with suboptimal temperature conditions, whereas no microbial growth was observed in toilets with suitable temperatures ($p < 0.001$ for both).

These findings emphasize the importance of maintaining appropriate thermal conditions in restroom areas to inhibit microbial proliferation. Adequate heating helps control fungal and bacterial growth, thereby supporting a healthier indoor environment for students (Table IX).

Table IX. *Relationship between temperature adequacy in toilet areas and the presence of microorganisms in school environments.*

		Suitable temperature in the toilet area			Total	P-value
		Yes	No	Not applicable		
Pigmented colonies	Yes	0	0	1	1	
	No	29	20	0	49	.000
	Total	29	20	1	50	
Aureo basidium spp	Yes	0	0	1	1	
	No	29	20	0	49	.000
	Total	29	20	1	50	

Wall damage, such as peeling paint or plaster, was significantly associated with the presence of various microorganisms in school environments. Red- and yellow-pigmented bacterial colonies were more frequently detected in areas with wall deterioration (p = 0.018). Similarly, *Candida spp., Mucor spp., and Aspergillus spp*. were significantly associated with damaged wall surfaces (p = 0.016–0.041).

These findings indicate that structural degradation provides niches that favor microbial colonization and growth. Maintaining building integrity through timely repairs and preventive maintenance is therefore critical to reduce microbiological contamination and to ensure safer indoor environments for students (Table X).

Table X. *Association between wall damage (peeling paint/plaster) and the presence of microorganisms in school environments.*

		Presence of parts of the wall where paint/plaster is falling off			Total	P-value
		Yes	No	Not applicable		
Red and yellow pigmented colonies	Yes	7	10	1	18	
	No	3	20	9	32	.018
	Total	10	30	10	50	
Candida spp	Yes	0	0	2	2	
	No	10	30	8	48	.016
	Total	10	30	10	50	
Mucor spp	Yes	7	8	5	20	
	No	3	22	5	30	.041
	Total	10	30	10	50	
Aspergillus spp	Yes	5	5	6	16	
	No	5	25	4	34	.016
	Total	10	30	10	50	

Moisture intrusion from ceilings was significantly associated with the presence of microorganisms in school environments. Red- and yellow-pigmented bacterial colonies were more frequently detected in areas with ceiling leaks (p = 0.047), whereas *Candida spp*. was also associated with moisture intrusion (p = 0.009).

These findings indicate that water infiltration from ceilings creates favorable conditions for microbial growth. Prompt repair of ceiling leaks and effective moisture control are therefore essential to minimize microbial proliferation and to protect students' health in indoor school environments (Table XI).

Table XI. *Association between ceiling moisture intrusion and the presence of microorganisms in school environments.*

		Moisture ingress from the ceiling			Total	P-value
		Yes	No	Not applicable		
Pigmented colonies - red and yellow	Yes	6	11	1	18	
	No	3	21	8	32	.047
	Total	9	32	9	50	
Candida spp	Yes	0	0	2	2	
	No	9	32	7	48	.009
	Total	9	32	9	50	

The presence of mold-cleaned surfaces was significantly associated with the occurrence of microorganisms. *Candida spp*. was detected only in locations where mold cleaning had not been performed (p = 0.037). In contrast, *Aspergillus spp*. was found more frequently on surfaces that had been previously cleaned but with incomplete removal (p = 0.035).

These results suggest that mold management practices, if incomplete or insufficient, may not fully prevent microbial proliferation. Regular, thorough cleaning combined with effective moisture control is therefore essential to reduce fungal colonization and to ensure healthier indoor environments for students (Table XII).

Table XII. *Association between mold-cleaned surfaces and the presence of microorganisms in school environments.*

		Part of the wall where there is mold and has been cleaned			Total	P-value
		Yes	No	Not applicable		
Candida spp	Yes	0	0	2	2	
	No	10	28	10	48	.037
	Total	10	28	12	50	
Aspergillus spp	Yes	4	5	7	16	
	No	6	23	5	34	.035
	Total	10	28	12	50	

The presence of pipe leaks was significantly associated with the detection of *Candida spp*. in school environments (p = 0.009). Candida spp. was identified exclusively in areas with pipe leaks, whereas no microbial growth was observed in areas without leaks.

These findings highlight the critical role of water system integrity in controlling microbial contamination. Prompt detection and repair of leaking pipes are therefore essential to prevent moisture accumulation and fungal proliferation, thereby protecting students' health and maintaining hygienic indoor environments (Table XIII).

Table XIII. *Association between pipe leaks and Candida spp. in school environments.*

		Pipe leaks			Pipe leaks	P-value
		Yes	No	Not applicable		
Candida spp	Yes	0	0	2	2	
	No	8	33	7	48	.009
	Total	8	33	9	50	

Multivariate analyses were conducted to evaluate the combined impact of multiple environmental and infrastructural variables on the presence of microorganisms in school environments. All four multivariate test statistics—Pillai's Trace (0.830), Wilks' Lambda (0.170), Hotelling's Trace (4.871), and Roy's Largest Root (4.871)—indicated statistically significant effects (p = 0.035), with a large effect size (Partial Eta Squared = 0.830).

These results suggest that the model, which included variables such as moisture levels, structural damage, presence of insects, temperature adequacy, and restroom facilities, collectively explains a substantial proportion of the variance in microbial contamination. The high Partial Eta Squared indicates that these environmental and infrastructural factors strongly influence the microbiological quality of school environments.

Overall, this multivariate analysis reinforces the importance of an integrated approach to environmental health, highlighting that structural integrity, hygiene practices, and environmental management jointly affect microbial proliferation in schools (Table XIV).

Table XIV. *Results of multivariate tests assessing the impact of variables in the model.*

Test	**Value**	**F**	**df (Hypothesis)**	**df (Error)**	**p-value**	**Partial Eta Squared**
Pillai's Trace	0.830	2.362	33	16	0.035	0.830
Wilks' Lambda	0.170	2.362	33	16	0.035	0.830
Hotelling's Trace	4.871	2.362	33	16	0.035	0.830
Roy's Largest Root	4.871	2.362	33	16	0035	0.830

Univariate analysis was performed to assess the individual impact of specific microbial indicators on overall microbial load in school environments. Red- and yellow-pigmented bacterial colonies showed a borderline significant association with microbial load (F = 4.033, p = 0.050) and a small effect size (Partial Eta Squared = 0.078). *Rhodotorula spp*., a yeast species, was significantly associated with microbial load (F = 8.183, p = 0.006) and exhibited a moderate effect size (Partial Eta Squared = 0.146).

These findings suggest that specific microorganisms, particularly *Rhodotorula spp*., contribute more substantially to overall microbial contamination in schools. Targeted monitoring and control of these indicator organisms may therefore provide an effective strategy for managing indoor microbiological quality (Table XV).

Table XV. *Results of univariate analysis of variables associated with microbial load and their statistical impact.*

Variables	F	p-value	Partial Eta Squared
Pigmented colonies - red and yellow	4.033	**0.050**	0.078
Rhodotorula spp.	8.183	**0.006**	0.146

Risk of Bias

All study procedures were standardized, including random selection of schools, use of validated data collection instruments, and controlled microbiological analyses. Consequently, the study demonstrates a low risk of bias (Tables II–XV).

DISCUSSION

The present study identified key structural and environmental determinants of microbiological contamination in Albanian primary schools. Moisture-related issues, including surface dampness, water infiltration, and ceiling leaks, were strongly associated with the presence of bacteria and fungi. These findings support the view that inadequate moisture control facilitates microbial proliferation in school environments and underscore the importance of building maintenance in managing indoor air quality.

Ventilation efficiency emerged as a critical factor linked with microbial contamination. Inadequate ventilation, indicated by elevated indoor CO_2 levels, is associated with higher concentrations of bioaerosols, including bacteria and fungi (10). Elevated CO_2, as a proxy for insufficient air exchange, co-varies with microbial concentrations and other indoor pollutants, highlighting that poor ventilation affects not only thermal comfort but also exposure to biological contaminants. Furthermore, insufficient ventilation has been associated with adverse outcomes among occupants, such as increased fatigue and respiratory symptoms, emphasizing the importance of maintaining adequate ventilation in educational settings (10).

In addition to ventilation challenges, the diversity and distribution of airborne microorganisms in school environments contribute to overall microbial exposure. Research from primary schools in Lithuania demonstrated that fungi and pollen are detected indoors across seasons, with genera such as *Penicillium, Cladosporium*, and *Acremonium* among the most abundant indoors, and their prevalence is influenced by school location and occupancy levels (11). These findings underscore the need for integrated environmental monitoring that considers both microbial and environmental parameters to fully characterize exposure risks in school settings.

Recent evidence suggests that integrated approaches combining improved ventilation with additional interventions may reduce indoor microbial loads more effectively than single measures alone. A pilot conceptual study in an Italian school showed that combined strategies, such as mechanical ventilation, probiotic-based sanitation, and introduction of plants, significantly reduced pathogen levels and antimicrobial resistance indicators in indoor air and on surfaces (12). Such multifaceted strategies represent a promising direction for enhancing indoor air quality and minimizing microbiological risks in school environments.

Taken together, these findings highlight that inadequate ventilation, structural conditions that favor microbial persistence, and environmental diversity are interacting determinants of indoor air quality in schools. This study extends current knowledge by quantifying the relationships between specific environmental and infrastructural factors and microbial indicators, thereby identifying key priorities for environmental health interventions in educational settings.

CONCLUSIONS

This pilot study highlights significant deficiencies in the hygienic-sanitary conditions and indoor environmental quality of primary schools in Albania. Moisture intrusion, inadequate ventilation, and structural damage were consistently associated with increased microbial contamination, including bacteria and fungi. The presence of indoor flush toilets, insect activity, and inappropriate temperature control further contributed to elevated microbial loads.

Our findings emphasize the need for targeted interventions to improve school infrastructure, ensure effective cleaning and maintenance protocols, and implement sustainable environmental monitoring programs. Strengthening ventilation, controlling humidity, and promptly repairing water leaks and structural damage are key priorities to reduce microbiological risks and protect children's health.

These results provide baseline evidence to inform policy development and public health strategies aimed at enhancing indoor air quality and hygiene standards in Albanian educational settings. Further studies with larger sample sizes and longitudinal monitoring are warranted to confirm these findings and to evaluate the effectiveness of remediation measures.

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