Fungal Contamination in Schools

Key Insights and Assessment Strategies

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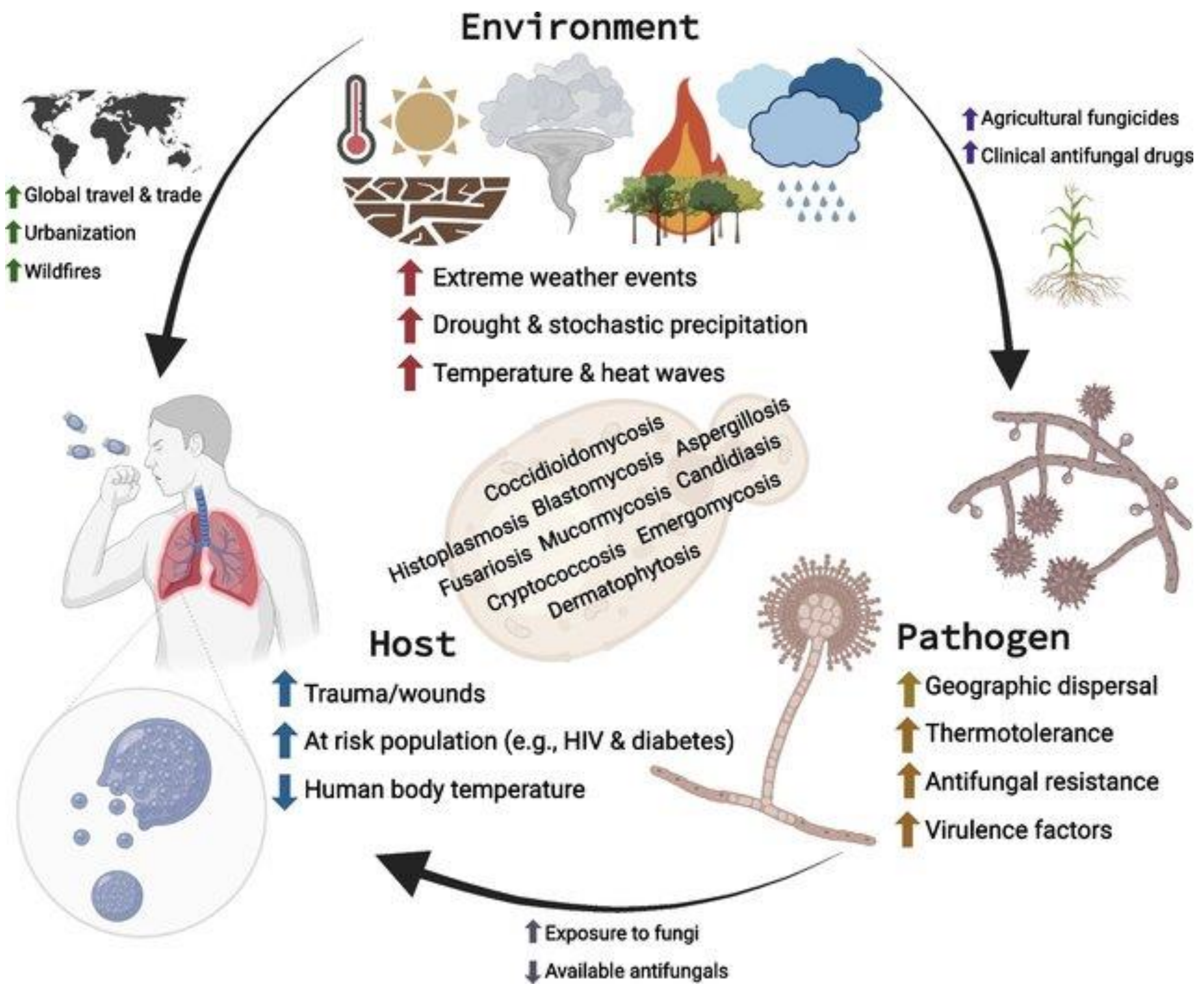
Introdução

Global Health Threat: Antimicrobial resistance and fungal pathogens (WHO, 2022).

Climate Change Impact: Warmer, wetter climates increase fungal dispersal and resistance (Seidel et al., 2024).

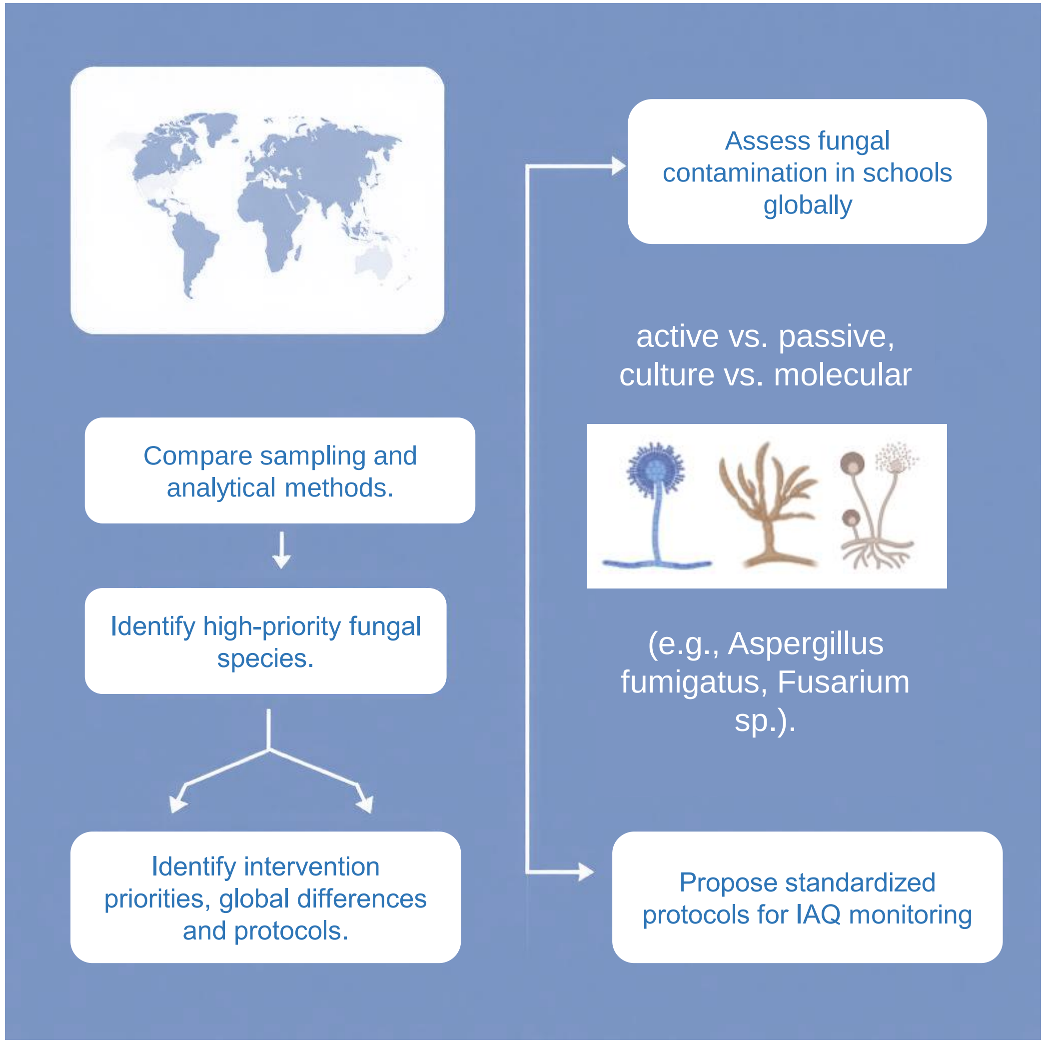
- **Focus:** Schools as high-risk environments for fungal exposure and health effects (respiratory issues, allergies, cognitive impacts)



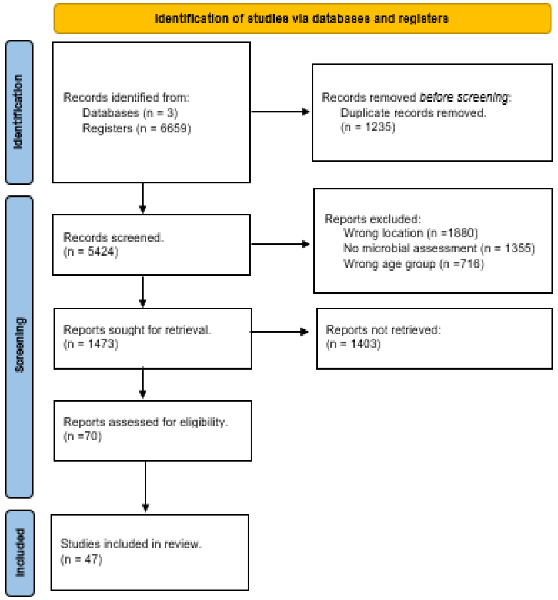
Salazar-Hamm, P., Torres-Cruz, T.J. The Impact of Climate Change on Human Fungal Pathogen Distribution and Disease Incidence. *Curr Clin Micro Rpt* **11**, 140–152 (2024). https://doi.org/10.1007/s40588-024-00224-x

Objectives

- Assess fungal contamination in schools globally.
- Compare sampling and analytical methods (active vs. passive, culture vs. molecular).
- Identify high-priority fungal species (e.g., *Aspergillus fumigatus*, *Fusarium* sp.).
- Propose standardized protocols for IAQ monitoring.



Methodology



Systematic review

Data Sources

PubMed, Scopus, Web of Science (2010–2024).

Inclusion Criteria

English, original studies, elementary schools, fungal focus.

6,659 articles screened

→ **47 selected** for analysis.

Variables Extracted:

Sampling methods, fungal species, climatic conditions, health outcomes.

Geographic Distribution

Europe
Portugal (N=3)
Finland (N=8)
Spain (N=2)
Netherlands (N=2)
Denmark (N=4)
Sweden (N=2)
Greece (N=1)
Italy (N=1)
Norway (N=1)
France (N=1)
Turkey (N=3)
England (N=1)
Germany (N=1)
Poland (N=1)
Lithuania (N=1)

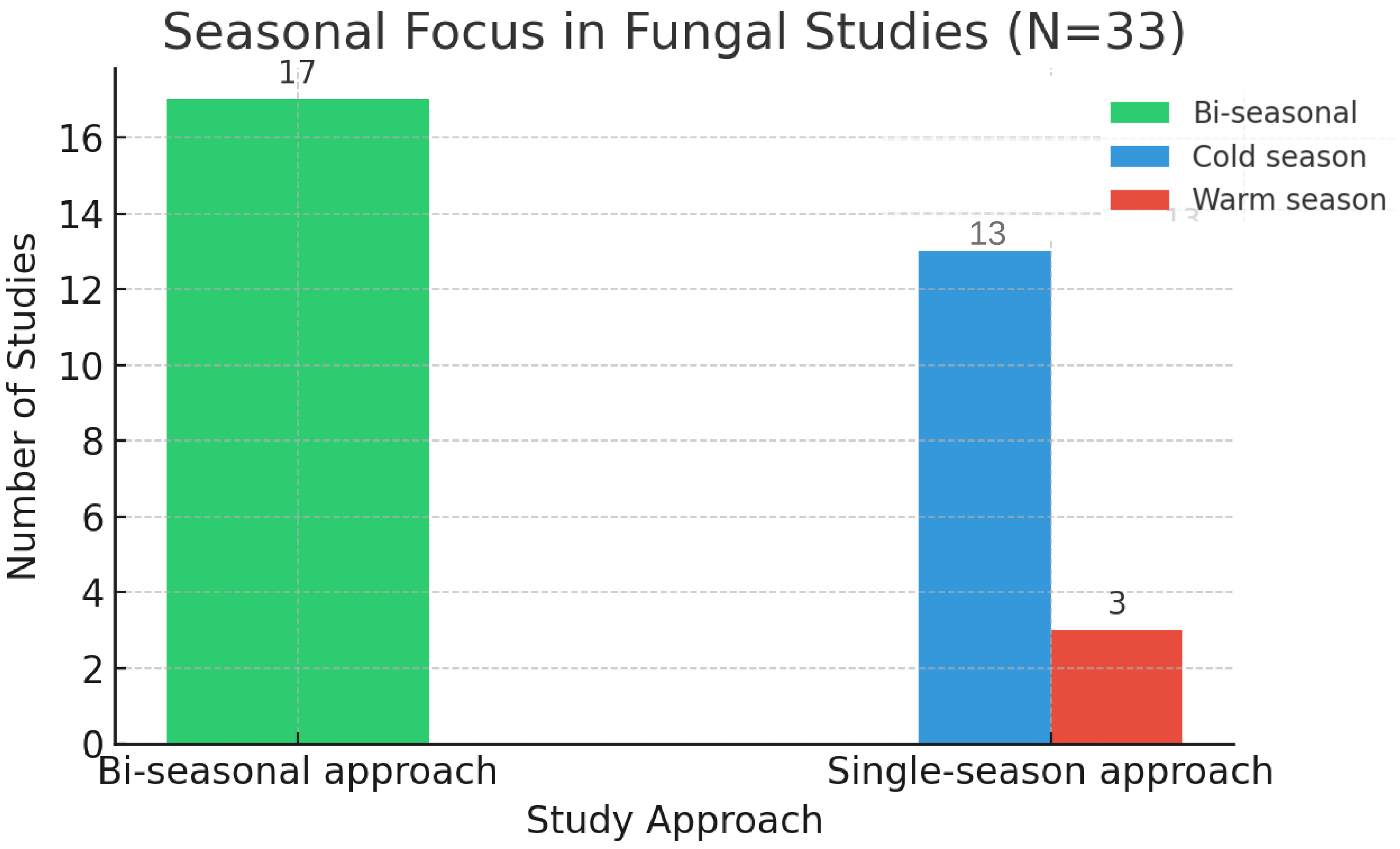
North America
USA (N=12)
Canada (N=2)

Asia
China (N=2)
Taiwan (N=3)
South Korea (N=2)
Saudi Arabia (N=1)

Africa
Egypt (N=1)
Ethiopia (N=1)

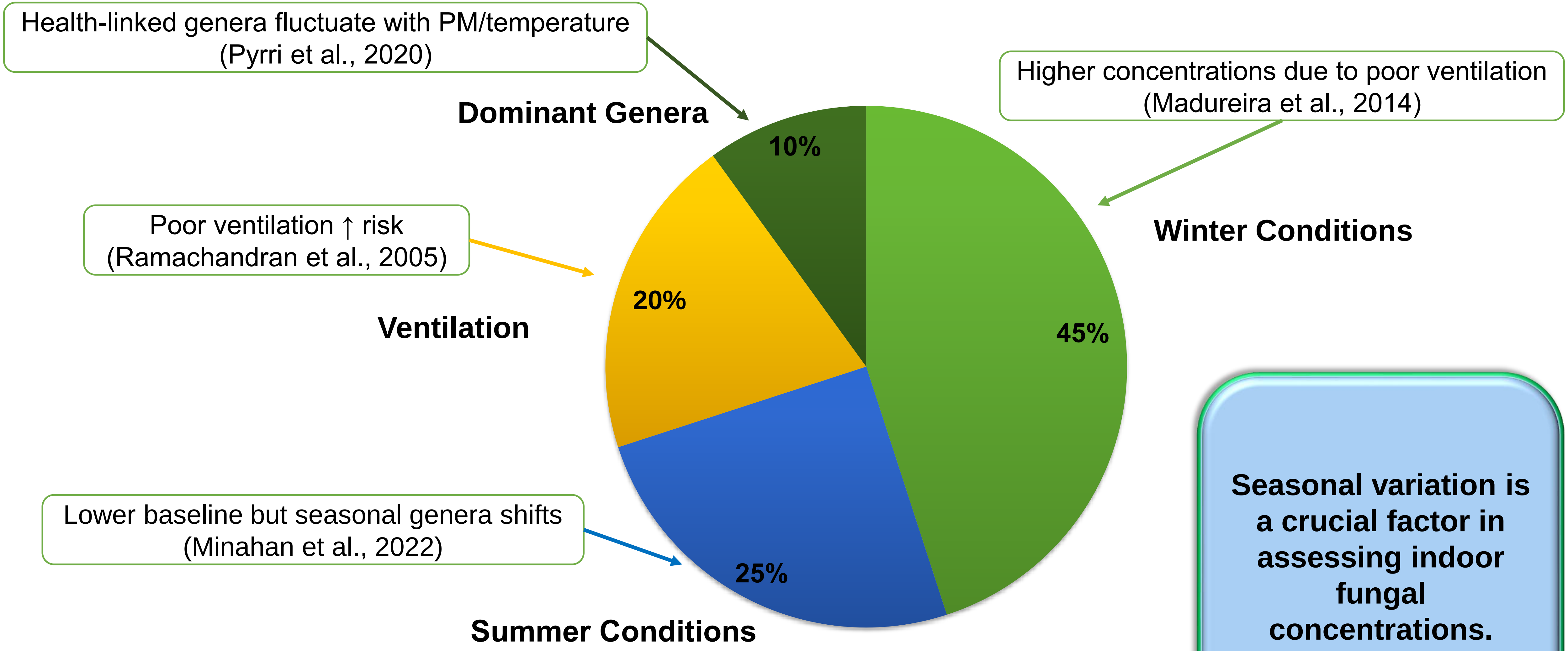
Oceania
Australia (N=1)

Seasonal Variations



Note: Data from a subset of 33/47 studies that considered seasonal variations.

Key Factors Affecting Indoor Fungal Concentrations



Seasonal variation is a crucial factor in assessing indoor fungal concentrations.

Sampling Methods

- 32 out of 47 studies use active sampling methods (with pumps, impactors, filters).
- 15 studies rely solely on passive methods (settled dust, electrostatic cloths, open dishes).
- Only 7 studies combine active and passive methods – a recommended approach for more comprehensive results.
- Active methods: controlled air collection, allow identification of viable particles via culture.
- Passive methods: simple, no equipment needed, suitable for long-term sampling.
- Passive samples require liquid extraction for analysis.
- Combining methods improves data quality and coverage.
- High methodological variability limits cross-study comparisons.

Passive	Method Category	Sampling Method/Samplers	References
Active	Impaction	Burkard Indoor Recording Air Sampler	Baxi, 2019; Baxi, 2013; Chen, 2014; Su, 2001; Pyrri, 2020
		Single-stage microbiologic air impactor (Merck MAS-100)	Cavaleiro Rufo, 2017; Mentese, 2009
		Single-stage Airldeal 3P impactor	Fonseca Gabriel, 2021; Madureira, 2014
		Andersen N6 single-stage impactor	Bartlett, 2004; Ramachandran, 2005; Zhang, 2013; Yamamoto, 2015
		Six-stage Andersen 10-800 impactor	Meklin, 2002; Meklin, 2003; Putus, 2004
		Mattson–Garvin slit-to-agar impactor	Foarde, 2004
		Andersen two-stage cascade impactor	Awad, 2018; Straus, 2003
	Filter	IOM Inhalable Dust Sampler (SKC Inc.)	Holst, 2016; Würtz, 2005
		Air-O-Cell Cassette (SKC/Zefon)	Santilli, 2003; Godwin, 2007
		Nucleopore filters (0.4 µm)	Kim, 2007; Simoni, 2011
		Millipore cassettes (0.45 µm)	Shin, 2015
		Fine Particle Sampler (PM2.5 filters)	Foarde, 2004
		MCE filter cassettes (0.8 µm)	Ramachandran, 2005; Nieto-Caballero, 2022
	Vacuum	Micro-vacuum sampler (IAQ-1294)	Ramachandran, 2005; Würtz, 2005
		Siemens Super XS vacuum cleaner	Simoni, 2011; Celtik, 2011
		Li'l Hummer backpack vacuum	Park, 2022
		HVS-3 vacuum sampler	Würtz, 2005
		Generic vacuum cleaners	Chatzidiakou, 2014; Hanson, 2016
	Tracer Gas	Tracer-gas decay method (acetone)	Kim, 2007
	Other	Sampling pumps (unspecified)	Lee, 2021
		Spot Sampler (Aerosol Devices)	Nieto-Caballero, 2022
Passive	Electrostatic Dust Collectors (EDC)	Electrostatic dust collectors (EDCs)	Jacobs, 2014; Holst, 2016; Viegas, 2020; Huttunen, 2019; Vornanen-Winqvist, 2020
	Settled Dust	Settled dust boxes (SDBs)	Holst, 2016; Huttunen, 2019; Zhang, 2011; Würtz, 2005 (aluminium foil)
		Passive sedimentation (open-dish/gravity plates)	Andualem, 2019; Aydogdu, 2005; Al-Qurashi, 2007; Hyvonen, 2020; Sauliene, 2023
	Swab/Surface Sampling	Surface swabs	Savilahti, 2001; Ejdys, 2011; Hyvonen, 2020; Sauliene, 2023

Analytical Methods

Culture-based

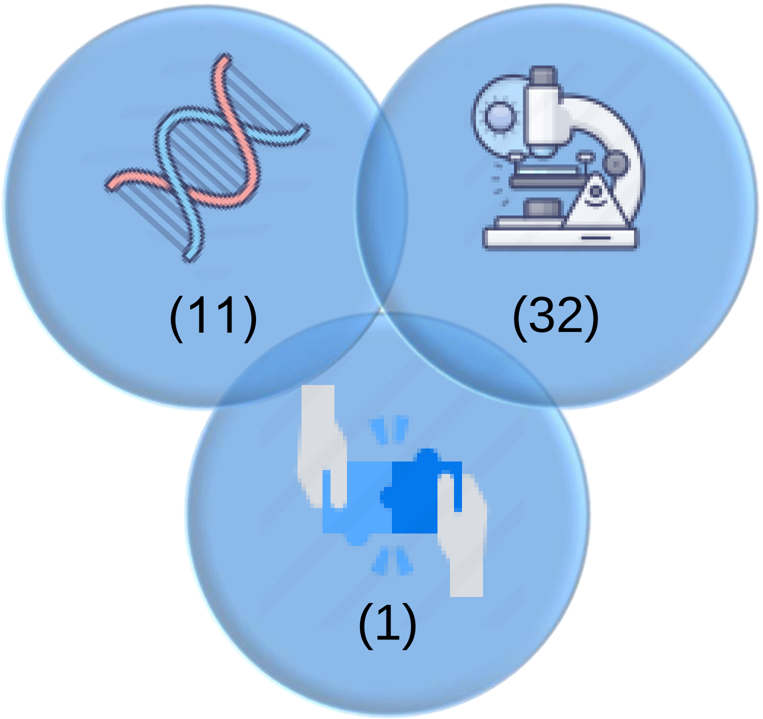
✔ **Morphological visualization** (direct observation of colonies/fungi)

✘ **Underestimates non-culturable fungi** (limited to viable samples)

Molecular

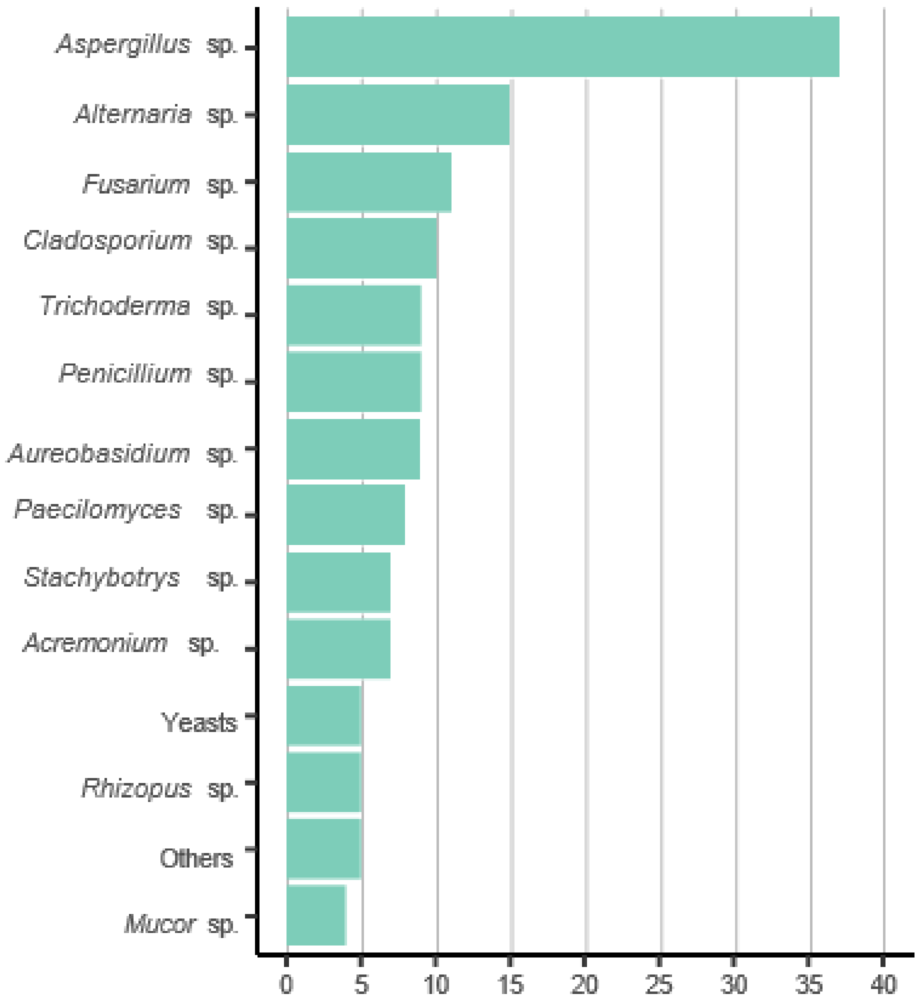
✔ **High sensitivity** (detects genetic material even at low levels)

✘ **Cannot assess viability** (does not distinguish live vs. dead organisms)



- **Culture-based methods were most common** (68%, 32/47 studies) but **underestimate non-culturable fungi**.
- **Molecular methods (qPCR/DNA sequencing)** offered **high sensitivity** (23%, 11/47) but **cannot assess viability** and are costly.
- **Only 1 study combined culture + molecular methods**, revealing a **critical gap** in hybrid approaches.
- **Most studies** (64%) **relied on single-method analyses**, limiting comprehensive risk assessment.

Prevalent Fungal Species



Aspergillus Dominance

Aspergillus was the most prevalent genus, detected in 42/47 studies (89%).

Yet, only 5 studies identified the critical-priority species *A. fumigatus* (WHO, 2022).

⚠ High-Priority Pathogens Underreported

Fusarium (11 studies) and *Mucorales* (9 studies)—both WHO high-priority fungi—were far less documented than *Aspergillus*.

Indoor School Environments Harbor Key Genera

11 genera (e.g., *Cladosporium*, *Penicillium*, *Stachybotrys*) were recurrent in elementary schools—potential hotspots for exposure.

Identification Bias Risk

Macroscopically recognizable genera (e.g., *Aspergillus*, *Penicillium*) may skew data, leaving other pathogens understudied.

Critical Gap

Low species-level resolution (only 16/42 *Aspergillus* studies specified sections) limits risk assessment accuracy.

Prevalent Fungal Species

Most prevalent species

Aspergillus niger, A. fumigatus, and *A. versicolor* were most frequently detected.

Identification challenges

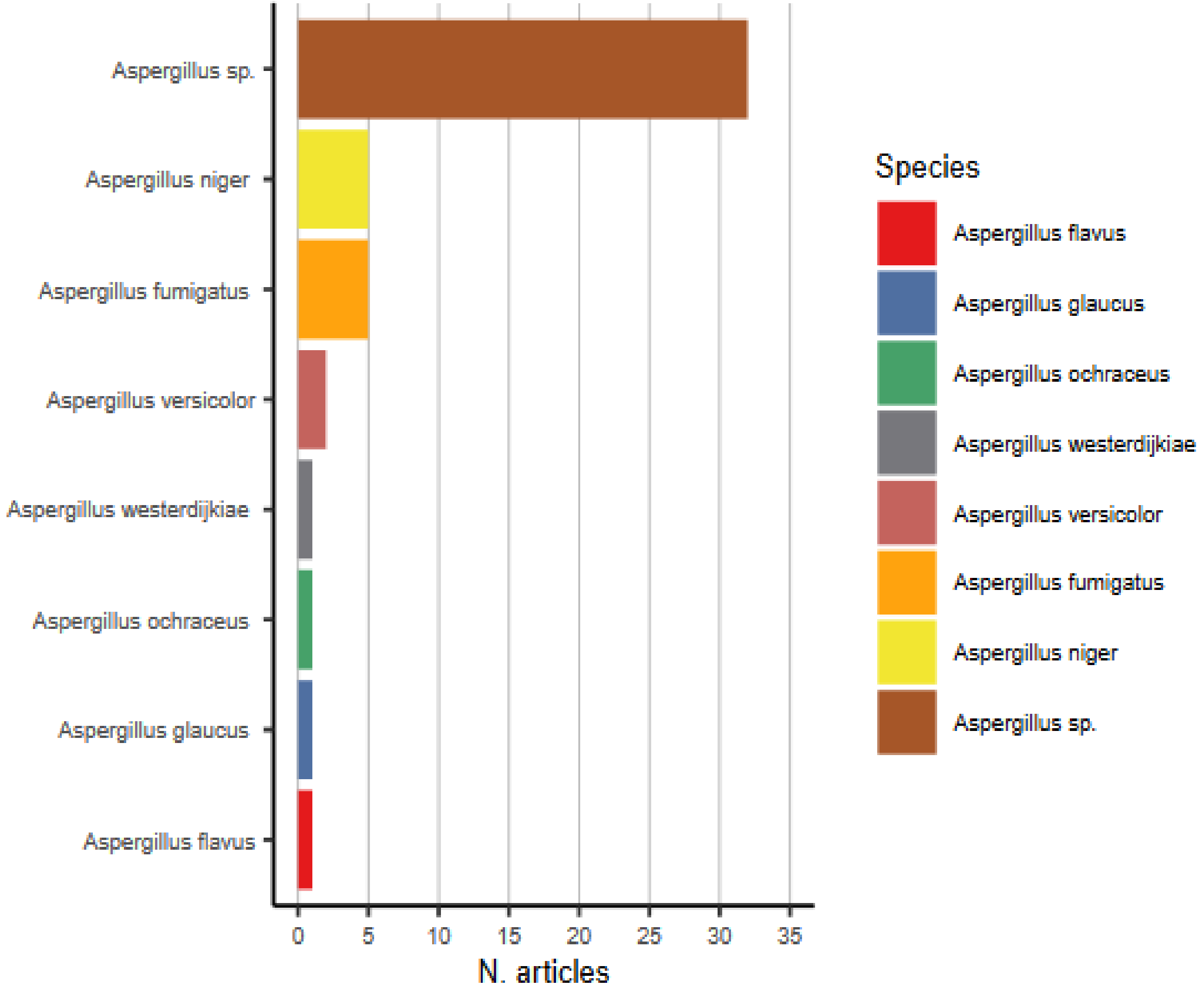
Traditional morphology-based classification is insufficient (many species are "cryptic").

Requires combined methods (morphological + biochemical + genetic) for accurate identification.

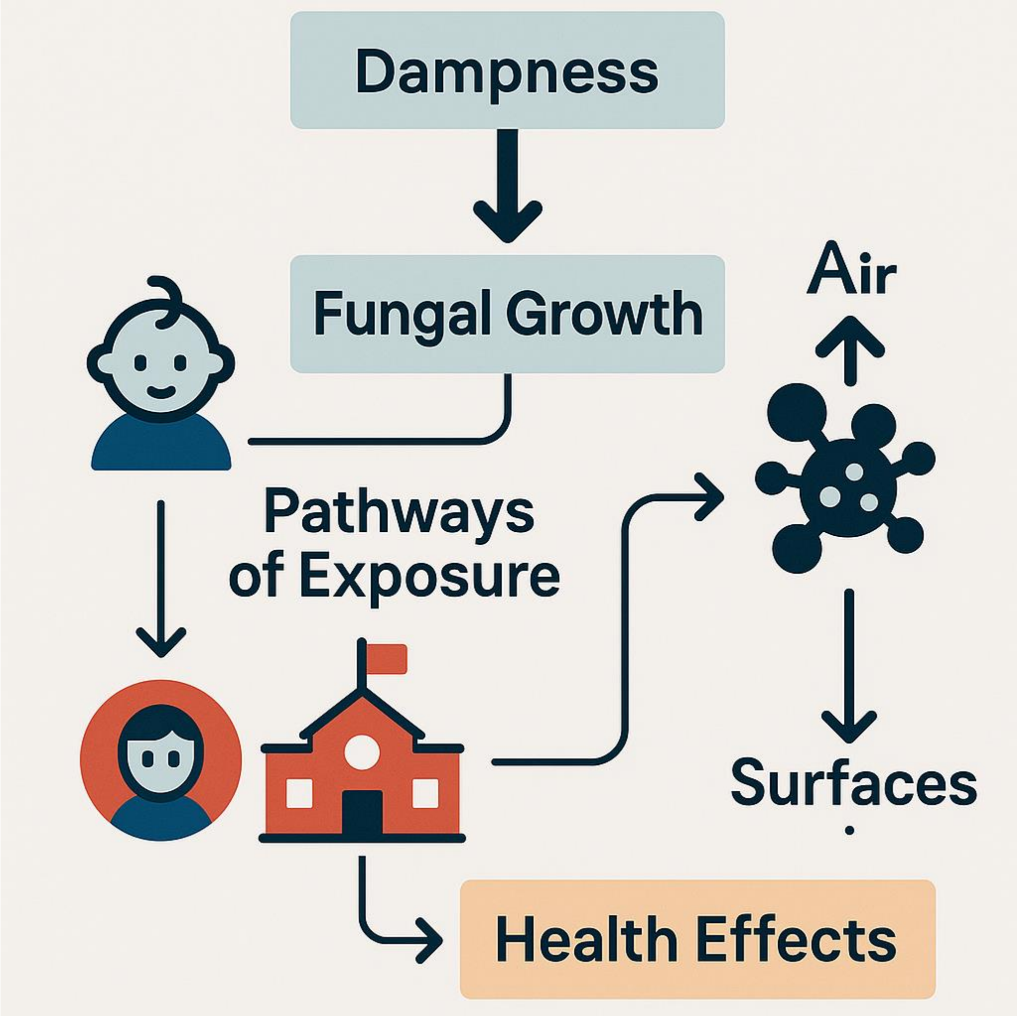
Clinical and public health importance

Section-level identification (e.g., *Fumigati*, *Flavi*) is critical for:

- Treatment decisions (antifungal resistance)
- Infection control and public health interventions



Health and Structural Impacts



- **Health Risks**: Exposure to fungi (*Aspergillus*, *Penicillium*, *Cladosporium*) in schools is linked to:
    - Respiratory issues (asthma, allergies, infections).
    - Cognitive dysfunction and reduced academic performance.
    - Chronic conditions from mycotoxin exposure (e.g., *Stachybotrys atra*).
- **Structural Damage**: Fungal growth compromises building integrity, especially in damp/moisture-prone areas.
- **Vulnerable Groups**: Children, immunocompromised individuals, and those with pre-existing conditions are at higher risk.

Limitations

InChildHealth

Methodological Gaps:

- 64% of studies used single-method approaches (culture or molecular), limiting comparability.
- Lack of standardized reporting (e.g., units like CFU/m³).

Geographic Bias: 54% of data from Europe; underrepresentation of tropical climates.

Health Data Gaps: Few studies directly link fungal exposure to dose-specific health outcomes.

Conclusions

Standardize Protocols:

Harmonize sampling (active + passive) and analysis (culture + molecular) methods.

Target High-Risk Fungi:

Prioritize *A. fumigatus*, *Fusarium*, Mucorales, and toxigenic species (*Stachybotrys*, *Aspergillus* section *Flavi*).

Seasonal/Geographic Monitoring:

Address variations in fungal loads (higher in winter due to poor ventilation).

Policy Action:

Integrate fungal monitoring into school health programs and building codes.

THANK YOU

Scan the QR code to access the full references

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