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Airborne Microbial Burden in School Classrooms: A Multidisciplinary Study of Indoor Air Quality and Health Implications

Introduction: Respiratory infections are a leading cause of morbidity in pediatric populations, with airborne transmission playing a significant role. The COVID-19 pandemic has underscored the impact of indoor air quality on human health, particularly in school environments, where children spend a substantial amount of time. Addressing this issue, an interdisciplinary group—the "Indoor Air Quality Group"—comprising microbiologists, pediatricians, architects, and engineers, was formed to investigate air quality in schools.

One of the group's primary objectives was to perform a microbiological analysis of airborne bacteria and fungi under varying environmental conditions. The study focused on five classrooms within a single school building in Montevideo, Uruguay, operating in two shifts. Sampling was conducted on a single day in November 2023 (spring). Microbial assessments included sedimentation on exposed petri plates and air filtration using the CAPTUS system (AravanLabs). Exposed plates containing Trypticase Soy Agar (TSA, for total bacteria), Sabouraud Agar, and Malt Extract Chloramphenicol Agar (SDA and MCA, for total fungi) were placed in two locations within each classroom. Air filtration lasted 10–20 minutes, with filters processed in PBS buffer and plated on TSA, SDA, and MCA. Plates were incubated at 37℃ for 2 days (TSA) and at 30℃ for 7 days (SDA and MCA). Microbial colony-forming units (CFUs) were quantified, and fungal colonies were identified at the genus level using macro- and micromorphological characteristics. Bacterial isolates from TSA were further identified through 16S rRNA sequencing. Environmental data, including CO_2 concentration, temperature, and humidity, were recorded using sensors and compared to microbial counts and classroom variables such as size and shift.

Results: The counts from the exposure plates in all samplings were similar for bacteria and fungi. The average bacterial counts in Trypticase soy agar were $2.5x10^3$ CFU/m³ (range: 0–6259), and the average fungal count in Malta chloramphenicol medium was $1.1x10^3$ CFU/m³ (range: 0–5995). The change of shift in the school did not affect the number of bacteria or fungi. A median CO_2 concentration of 1140 ppm (range: 530–2019 ppm), a temperature of 20℃ (15–24℃), and a humidity of 67.6% (51–86%) were recorded. A significant correlation ($p < 0.001$) was observed between elevated CO_2 levels and increased microbial CFUs, reflecting the impact of occupant activity on indoor air quality.

Fungal genera identified included Penicillium, Alternaria, and Rhodotorula, with potential pathogens such as Aspergillus also detected. Bacteria isolated from filtered air were primarily from the genera Staphylococcus (e.g., S. hominis, S. epidermidis, S. capitis, S. saprophyticus) and Micrococcus. Opportunistic bacteria and pathogens, including Pseudomonas and Moraxella, were also identified.

Conclusions: These findings highlight a measurable correlation between increased CO_2 levels, indicative of poor ventilation, and higher microbial counts, underscoring the importance of air quality monitoring in schools. The interdisciplinary approach employed in this study enhances understanding of airborne microbial dynamics in educational settings. Future research should incorporate methods to detect non-culturable microorganisms and identify common airborne pathogens that children are exposed to during school hours. This knowledge is critical for developing evidence-based interventions to improve indoor air quality and safeguard children's health.

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