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Original Research Article

PREVALENCE OF AIRBORNE PATHOGENIC FUNGI IN EDUCATIONAL BUILDINGS IN SANA'A CITY, YEMEN

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ABSTRACT

Objective: The ambient air quality within educational institutions significantly influences the health and well-being of students, educators, and all associated personnel, thereby impacting the broader community's health. This investigation aimed to isolate and identify airborne pathogenic and opportunistic fungi in the educational settings of Sana'a city, Yemen.

Methods: The research encompassed four distinct educational structures: a government-run middle school for girls (School 1), a government-run middle school for boys (School 2), a private high school for girls (School 3), and a private high school for boys (School 4). Utilizing the open plate technique, a total of 64 air samples were meticulously collected from various departments within these institutions, properly labeled, and subsequently transported to a laboratory for detailed examination and analysis employing standardized microbiological methodologies. Through morphological and microscopic examination techniques, a diversity of fungal isolates was identified.

Results: The findings disclosed the isolation of 50 pathogenic and opportunistic fungal isolates across the four schools in Sana'a, distributed as follows: 10 isolates (20%) from School 1, 18 isolates (36%) from School 2, 8 isolates (16%) from School 3, and 14 isolates (28%) from School 4. Notably, School 2 harbored the highest number of isolates at 36%, while School 3 exhibited the lowest at 16%. A statistically significant variation (P<0.05) was observed among the fungal isolates and the schools. Of the total isolates, only 11 (22%) were identified as pathogenic, whereas 39 (78%) were classified as opportunistic fungi. These comprised eight fungal genera: *Rhizopus, Cladosporium, Aspergillus, Curvularia, Penicillium, Alternaria, Trichophyton, and Chrysosporium*, with respective frequencies of 7 (14%), 3 (6%), 21 (42%), 2 (4%), 11 (22%), 3 (6%), 1 (2%), and 2 (4%). Aspergillus was the most prevalent genus 2 identified, whereas Trichophyton was the least prevalent. No significant differences (P<0.05) were noted among these fungal genera. Furthermore, the distribution of pathogenic fungi across the schools was as follows: 3 (6%) in School 1, 5 (10%) in School 2, 1 (2%) in School 3, and 2 (4%) in School 4, with no significant variance observed among the schools regarding pathogenic fungi prevalence. The investigation highlighted a predominant presence of pathogenic fungi within classroom sections (CR) compared to teachers' rooms (TR).

Conclusions: The study elucidates the presence of various pathogenic fungi within school environments in Sana'a, underscoring the necessity for enhanced hygiene practices in these educational establishments.

Keywords: Isolation, Identification, Airborne Fungi, Sana'a, Schools, Yemen, Pathogenic fungi

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1. INTRODUCTION

The well-being of infrastructures within educational settings, including schools and universities, is recognized as a critical global issue, particularly due to the susceptibility of students to microbial diseases caused by entities such as fungi, bacteria, and viruses. Educational environments are replete with a diverse array of microorganisms, among which airborne microbes represent a significant concern. Predominantly, fungi and bacteria are the major microbial types encountered within these settings. The propagation of microbial contaminants in such environments can be attributed to a variety of sources, including air currents, dust particles, winds, and the collective presence of teachers, employees, students, and visitors (Beggs, 2003). The quality of indoor air is a paramount concern affecting human health, considering the extensive duration—over 90% of an individual's life—spent indoors, whether it be in residential spaces, office buildings, or classrooms (Hayleeyesus and Manaye, 2014; Liu et al., 2017). Factors contributing to indoor air pollution include suboptimal building conditions, such as the choice of building materials, the efficiency of air conditioning systems, ventilation rates, and human-related factors like overcrowding in limited spaces (Wemedo et al., 2012; Gilbert et al., 2010; Huttunen et al., 2001). Certain pathogenic fungi, which are causative agents of mycotic diseases, exist freely in nature and induce illnesses through the inhalation of fungal spores or via direct contactinjuries. Other fungi, part of the normal flora in human and animal bodies under conditions of strong immunity, can become pathogenic during periods of immune deficiency. Additionally, certain fungi are known to produce mycotoxins, toxic compounds that can cause diseases (Barron, 1968). The contamination of indoor air by microorganisms, including bacteria, fungi, and viruses, is a significant factor affecting air quality and can lead to allergenic diseases. Airborne fungi, particularly species such as Trichophyton spp., Penicillium spp., Aspergillus spp., Rhizopus spp., Cladosporium spp., Fusarium spp., and Curvularia spp., have been identified as prevalent contaminants in laboratory rooms, libraries, hospitals, and schools, and are associated with mycotic diseases (Alangaden, 2011; Patterson and Strek, 2014; Vonberg and Gastmeier, 2006; Perdelli et al., 2006) Mycotic diseases are typically chronic, attributable to the slow growth rate of fungi, and are classified based on the degree of tissue involvement and the mode of entry into the host organism into five categories: superficial, cutaneous, subcutaneous, systemic, and opportunistic infections (Tortora et al., 2007). Dermatophytes, also referred to as keratinophilic fungi, are capable of degrading the keratin layer in the skin of humans and animals through the action of enzymatic products (Prescott et al., 2001). Fungal spores constitute a significant portion of the biological particulate matter in both indoor and outdoor air environments, contributing to air pollution and associated health issues (Durugbo et al., 2013; Pickering et al., 1992; Fang et al., 2007). The widespread presence of airborne fungal spores is linked to adverse health outcomes (Dubey, 2016), emphasizing the importance of addressing air quality within educational institutions to mitigate potential health risks. Prolonged exposure to elevated levels of harmful airborne fungal spores has been documented to precipitate allergic reactions, respiratory symptoms, and pulmonary infections, ultimately impairing the immune system (Tariq et al., 1996; Hargreaves et al., 2003; Atalay et al., 2016; Renpenning-Carrasco et al., 2017). To date, over 80 fungal genera have been implicated in respiratory allergies (Fang et al., 2007). The infectious stages of these fungi include hyphae and arthrospores, which can persist in a latency phase for up to 24 months within the loose vacuoles of host keratinocytes (Richardson, 1990). Airborne fungal conidia, with concentrations ranging approximately from 1 to 100 conidia per cubic meter, are ubiquitously inhaled across populations (Buczynska et al., 2007). Recent decades have seen a notable increase in the incidence of severe fungal diseases. Opportunistic fungal pathogens, particularly from the genera Candida and Aspergillus, are capable of invading the human body, leading to mucosal and skin infections or even deep-seated mycoses affecting nearly all internal organs, with immunocompromised individuals being especially vulnerable (Probst et al., 2010). Genera such as Alternaria, Penicillium, Aspergillus, and Cladosporium are frequently associated with hypersensitivity reactions (Nageen et al., 2021). Among the myriad of fungi, only a select few species are recognized as pathogenic to humans. The most common fungal infections diagnosed in humans are attributable to species from the Candida and Aspergillus genera. Moreover, even non-pathogenic fungi carry the potential to induce mycotoxicosis and infections of the ear and nail (Abbasi and Samaei, 2019). These fungi are omnipresent, either acquired from environmental exposures or as constituents of the normal endogenous flora (Perfect and Casadevall, 2006). Numerous human fungal pathogens exhibit dimorphism, demonstrating reversible transitions between yeast and hyphal forms (Klein and Tebbets, 2007). International and national guidelines on indoor air quality often address concentrations of airborne microorganisms, including fungi. These guidelines typically specify acceptable levels of fungal spores to minimize health risks, although the exact standards can vary based on the governing body or country. This study aimed to isolate and characterize airborne pathogenic fungi present in the educational environments of Sana'a city, Yemen.

2. MATERIAL AND METHODOLOGY

2.1 Sampling Sites:

To divide a city into four representative sectors to collect air samples from schools to isolate pathogenic fungi, a methodical approach based on scientific principles and statistical methods was employed to ensure the representativeness and reliability of the data. The objective was to collect air samples from these schools across the city to isolate and identify pathogenic fungi, ensuring that the sectors chosen represent different geographical, environmental, and socio-economic conditions that might influence fungal diversity and concentration. The city was divided into sectors based on criteria that could affect fungal spore distribution, such as geographical location 5 (North, South, East, and West), environmental factors (areas near industrial zones, green parks, water bodies, and dense residential areas), and socio-economic status (different sectors might have schools with varying levels of maintenance, cleanliness, and infrastructure quality, which can influence indoor air quality). The stratified random sampling was employed to ensure each sector was adequately represented: Within each sector, the schools were randomly selected for sampling. This method ensures diversity within each sector is captured, minimizing bias. The research was executed within four educational edifices in Sana'a city, Yemen, comprising: a government middle school for girls (it will be symbolized by “School 1”), a government middle school for boys (it will be symbolized by “School 2”), a private high school for girls (it will be symbolized by “School 3”), and a private high school for boys (it will be symbolized by “School 4”). The sample size was calculated using the following formula: $n= Z^2 \times p(1-p)/E^2$ where n= sample size, Z= Z-score (1.96 for 95% confidence), p= estimated prevalence of pathogenic fungi (0.5), and E= margin of error (0.05 for 5%) According to these data, the sample size was approximately 384. A finite population correction was adjusted using the following formula: $n_{adjusted}= n/1+(n-1/N)$ where N= number of schools in each sector Considering a hypothetical total population size (N) of 1000 schools in a sector, the adjusted sample size was 278.

2.2 Sampling Collection and experimental Design:

To ensure standardization of the experimental design, the same sampling technique, duration, and type of culture media were used across all schools to maintain consistency. The spring season, characterized by the peak concentration of fungal aerosols, was selected for the collection of samples. This decision was informed by literature indicating significant seasonal variations in bioaerosol concentrations, encompassing both bacterial and fungal aerosols, and their correlation with diverse meteorological factors

(Jones and Harrison, 2004; Li et al., 2017). A total of 64 fungal isolates were obtained from the total collected samples, the fungal aerosol isolates were gathered from four distinct sections within each institution, namely: classrooms (CR), teachers' rooms (TR), school bathrooms (SB), and school yards (SY), utilizing the open plate technique. This method involved the employment of standard 90 mm Petri dishes, filled with 20 ml of either Sabouraud Dextrose Agar (SDA) or Potato Dextrose Agar (PDA) culture media. These media were augmented with 50µg/L of Cycloheximide and Chloramphenicol to inhibit the growth of saprophytic fungi and bacteria, as delineated by (Fathi and AL-Samari 2000; Singh and Beena 2003; and Golah et al., 2017), or alternatively, a single drop of 30% Ammonium hydroxide was added to solid media for the same purpose (Aubaid, 1997). The Petri dishes were exposed to the air for six hours, from 8:30 a.m. (prior to the students' arrival at school) to 2:30 p.m. (following their departure), in alignment with protocols established by (Koneman et al., 1978). All samples were meticulously labeled and transported to a laboratory for examination and analysis, employing methodologies as described by (Miranda and Silva, 2005; Chaya and Sushil, 2007). Sabouraud Dextrose Agar (SDA) (Oxoid) was prepared and utilized in accordance with the procedures outlined by (Zomorodian et al. 2002).

2.3 Incubation, Purification, Isolation, and Identification of Fungi:

The samples underwent incubation at 29°C for a duration ranging from 3 to 25 days (Benson, 2001). All fungal isolates were identified through standard microbiological methods, focusing on morphological characteristics, colony appearance, and microscopic examination of spores and hyphal features using lactophenol cotton blue preparation. These processes were conducted following the methodologies specified by (Kreger–Van 1984; Kwon-Chung and Bennett 1992; Weitzman et al., 1995; Rajash, and Rattan 2008; and Golah et al., 2017). The isolation, purification, and identification procedures were carried out in the laboratories of the Agricultural Veterinary Institute located in Sana'a, City.

2.4 Statistical analysis:

Statistical assessment was conducted using SPSS® V22 for descriptive analysis, as described by (Daniel 1987; and Ponce et al., 2023). The statistical analysis revealed a significant difference between the various groups at a significance level of 0.05.

3. RESULT

The percentage distribution of pathogenic and opportunistic fungal species detected in four schools, referred to as School 1, School 2, School 3, and School 4, is depicted in Figure 1.

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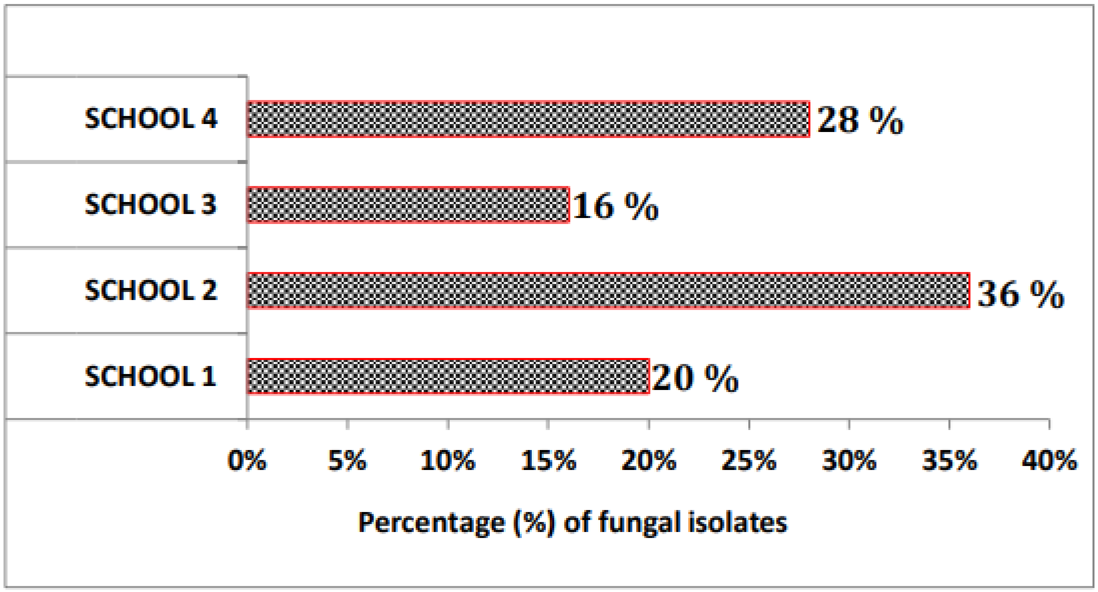

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Figure 1. Comparative analysis of pathogenic and opportunistic fungal species prevalence across four schools with statistical significance notation P< 0.05, (P-value = 0.003).

The data presented herein illustrates the relative abundance of these fungal species in relation to the overall fungal isolates obtained from the air samples collected from these educational institutions. In particular, the distribution of percentages is as follows: School 1 (20%), School 2 (36%), School 3 (16%), and School 4 (28%).

Figure 2 illustrates the distribution of pathogenic and opportunistic fungal species isolated from air samples collected across all schools involved in the study. The data are presented as percentages: Pathogenic fungi account for 22% of the total fungal isolates, and opportunistic fungi constitute the larger share, with 78% of the total fungal isolates. The figure indicates that the majority of fungal species identified in the school environments are opportunistic, which means they might not cause diseases in healthy individuals but can pose a risk to those with compromised immune systems. In contrast, a smaller but significant portion of the isolates are pathogenic fungi, which have the potential to cause diseases in both healthy and immunocompromised individuals.

Whereas, the Figure 3 presents the percentage distribution and types of fungal genera isolated from air samples across all schools involved in the study

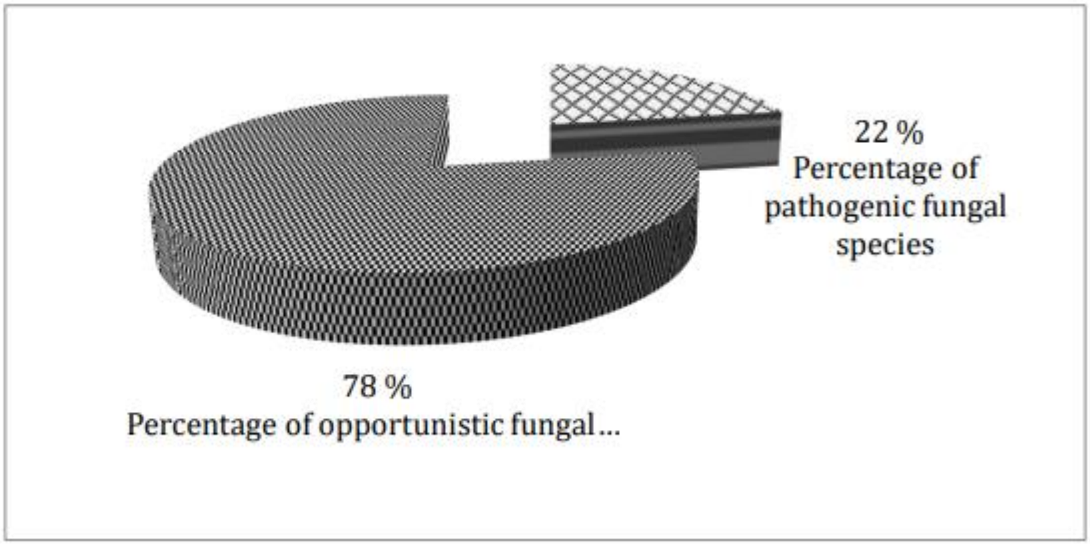

Figure 2. Distribution of pathogenic versus opportunistic fungal species across schools with no significant differences in prevalence(P<0.05), (P-value =0.478).

The figure details the proportions of each fungal genus as follows: Rhizopus (14%), Cladosporium: (6%), Aspergillus (42%), Curvularia (4%), Penicillium (22%), Alternaria (6%), Trichophyton (2%), Chrysosporium (4%). Figure 4 illustrates the proportions of pathogenic and opportunistic fungi that were obtained from air samples collected from four different schools. The primary objective of this analysis is to compare the occurrence of opportunistic fungi with pathogenic fungi in these educational settings. The distribution rates of pathogenic and opportunistic fungi in each educational institution are as follows: School 1 includes 6% pathogenic fungus and 20% opportunistic fungi. School 2 has a prevalence of 10% pathogenic fungus and 30% opportunistic fungi. Regarding School 3, there are 2% pathogenic fungus and 10% opportunistic fungi. School 4 has a composition of 4% pathogenic fungus and 18% opportunistic fungi.

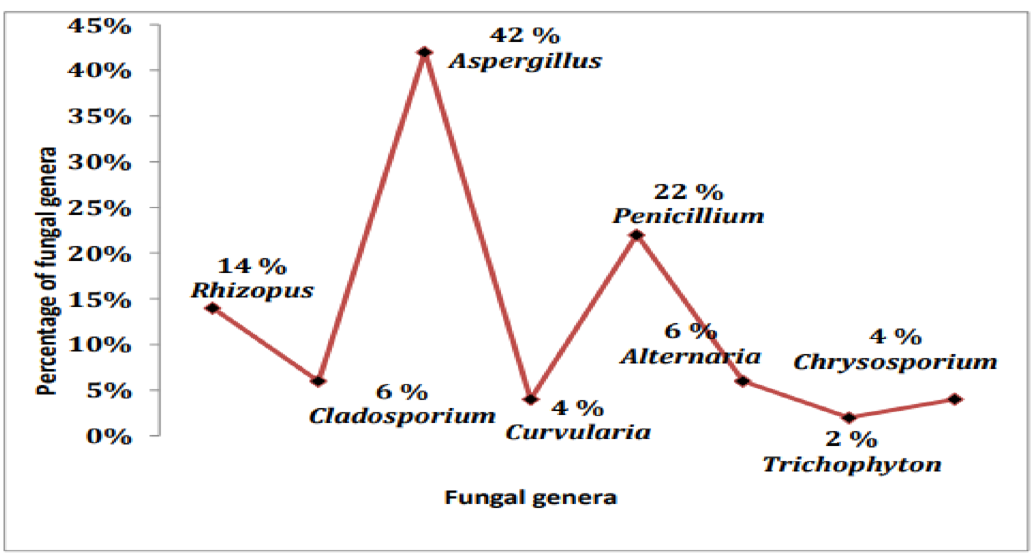

Figure 3. Prevalence of various fungal genera detected in all schools selected in this work.

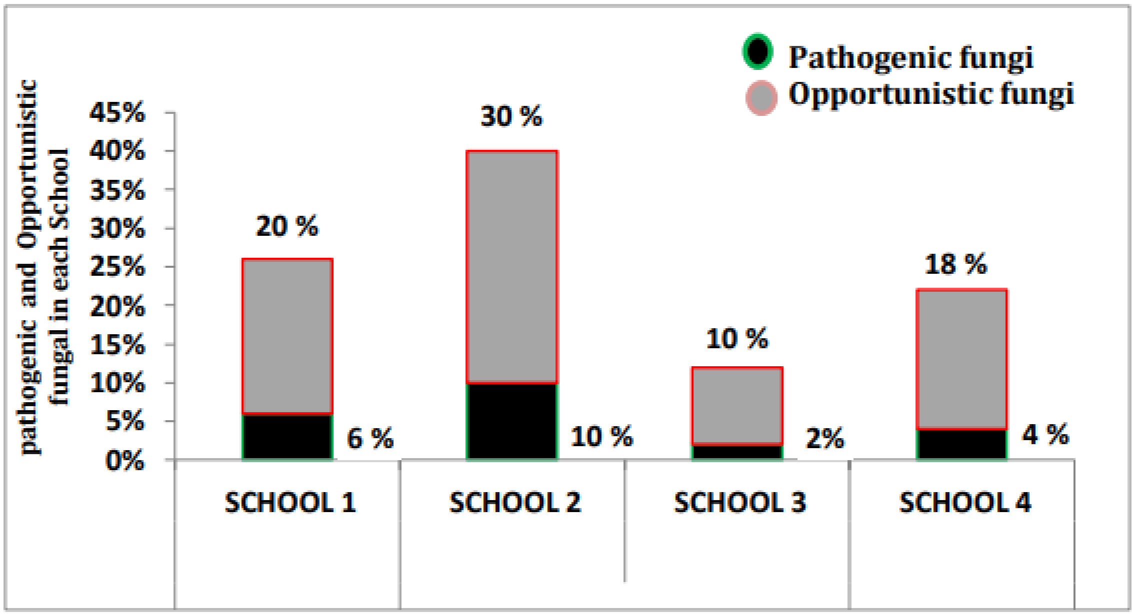

Figure 4. A Detailed percentage breakdown of the prevalence of fungal species in four schools for comparison. The relationship between schools and opportunistic fungus is significantly different (P<0.05, P-value = 0.0002) There were no significant differences (P<0.05), P-value = 0.0002) There were no significant differences(P<0.05) found in the percentage of harmful fungus in each school(P-value=0.173).

Figure 5 illustrates the distribution of pathogenic fungi percentages across different departments (classrooms, bathrooms, teacher rooms, and school yards) within each of the four schools. Specifically, School 1 showed pathogenic fungi only in classrooms (18%), with no presence in other departments. School 2 displayed a broader distribution with classrooms (27%), school yards (9%), and bathrooms (18%) affected. Schools 3 and 4 had no pathogenic fungi detected in classrooms, teacher rooms, or bathrooms, but School 4 showed a 9% presence in school yards and 18% in bathrooms. No significant differences were found across the schools and departments regarding the prevalence of pathogenic fungi, as indicated by a P-value of 0.560.

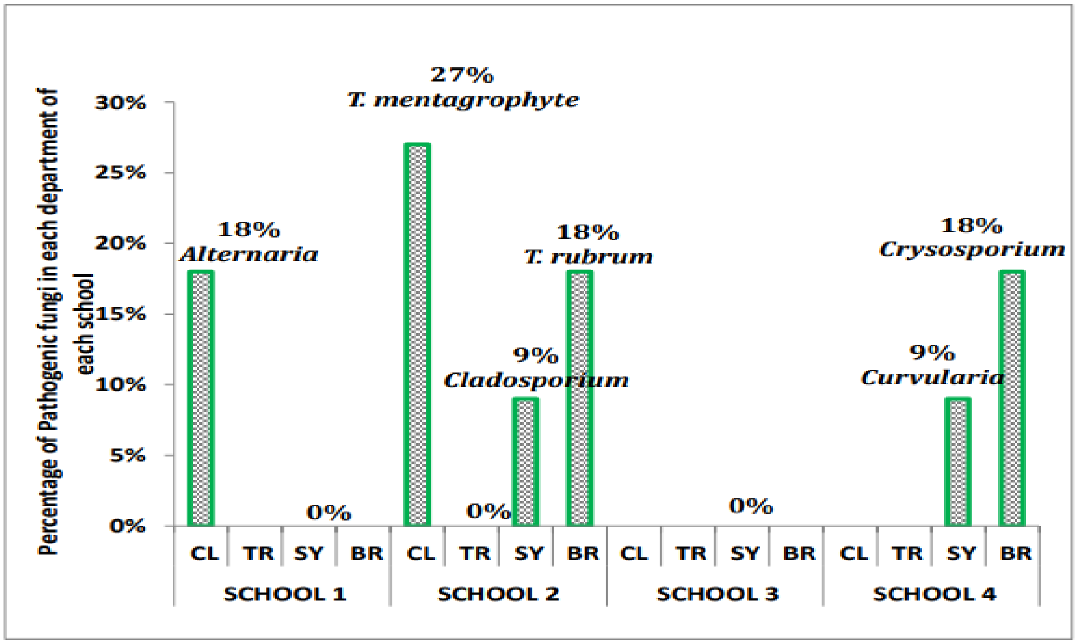

Figure 5. Distribution of pathogenic fungi prevalence by department within each school: classroom (CR), bathroom (BR), teacher room (TR), and school yard (SY)analysis. (P- value=0.560).

4. DISCUSSION

The study aimed to isolate and identify airborne pathogenic and opportunistic fungi within educational settings in Sana'a, Yemen. Sampling from four schools, it utilized standard microbiological methods to examine air samples, revealing a significant presence of both pathogenic (22%) and opportunistic fungi (78%), with Aspergillus being the most prevalent genus. The research confirms the variability in fungal contamination across schools, highlighting the necessity for improved hygiene and maintenance practices to safeguard students and staff's health. The results indicate a statistically significant difference in the distribution of pathogenic and opportunistic fungi among the four schools, as evidenced by a reported P-value of 0.003. This suggests that there is a significant variation in fungal contamination levels among these educational institutions. The observed diversity may be ascribed to disparities in environmental conditions, maintenance methodologies, construction materials, and occupancy trends across educational institutions. The elevated percentage seen in School 2 (36%) may suggest the presence of conditions that are more favorable for fungal proliferation or less efficient cleaning and maintenance procedures in comparison to the remaining schools. On the other hand, School 3, which exhibits the lowest percentage (16%), may possess circumstances that are less conducive to the proliferation of fungi or potentially boast superior hygiene and environmental management protocols The given P-value emphasizes the statistical significance, stressing the need to address environmental and maintenance variables in schools in order to reduce the risk of exposure to pathogenic and opportunistic fungi. Additionally, it highlights the necessity of implementing focused interventions in educational institutions characterized by elevated levels of contamination, with the aim of enhancing indoor air quality and safeguarding the well-being of both students and staff members (Jaffal et al., 1997; and Golah et al., 2017). The presented figure underscores the significance of consistent monitoring and evaluation of air quality in educational environments, offering significant perspectives for school administrators, health authorities, and legislators in their efforts to

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establish secure and conducive learning spaces. A key point noted in the figure 2 is the statistical analysis outcome, which shows no significant differences at (P<0.05) (with a reported (P-value of 0.478) This suggests that, across the schools from which samples were collected, the proportion of pathogenic to opportunistic fungal species is relatively consistent. The lack of significant variation indicates that the environmental conditions, maintenance practices, and other factors that could influence the prevalence of different types of fungal species might be similar across the schools or that the differences are not substantial enough to result in a statistically significant variation in the proportions of pathogenic and opportunistic fungi. The conclusions of this test disagree with the results reported by (Saad, 2003). 92% of the observed fungus were opportunistic, while 8% were pathogenic. This consistency in the distribution of fungal types across different educational settings can inform public health strategies and indoor air quality management practices. It underscores the need for regular monitoring and control measures to manage the levels of opportunistic fungi, thereby protecting the health of all individuals, particularly those with weakened immune systems. Additionally, the presence of pathogenic fungi, although smaller in percentage, highlights the importance of maintaining high standards of cleanliness and air quality to prevent potential health risks associated with these harmful microorganisms. The outcome of figure 3 aligns with the research conducted by (Sepahvand et al., 2013; Mohammed and AL-Jibouri, 2015), whereas the lower genus of Trichophyton was identified. No statistically significant differences were identified among these fungal genera at a significance level of 0.05. The data illustrate that Aspergillus is the most prevalent genus, accounting for 42% of the fungal isolates, followed by Penicillium with 22%. The least prevalent are Trichophyton and Chrysosporium, each constituting a smaller fraction of the isolates. The presence of these genera highlights a diverse fungal community within the school environments from which the samples were collected A notable aspect of the figure is the statistical analysis outcome, indicating no significant differences at (P<0.05) (with a reported P-value of 0.543) among these fungal genera. This suggests that, despite the variation in percentages among the fungal types, the differences are not statistically significant. In other words, the variability in the presence of these fungal genera across the sampled schools does not reach a level of statistical significance that would indicate a distinct pattern or distribution that could be associated with specific environmental conditions or factors within the schools. The predominance of Aspergillus in the samples is noteworthy, given this genus's relevance to public health due to its potential to cause various diseases, especially in immunocompromised individuals. The presence of Penicillium, another genus of concern due to its allergenic properties, also underscores the need for effective indoor air quality management in schools to mitigate potential health risks. The lack of significant differences among the fungal genera across the schools suggests arelatively uniform fungal flora in terms of the genera's presence. This uniformity could imply that the schools share similar environmental conditions or that the methods used for fungal control and building maintenance do not selectively affect specific fungal genera. The analysis of Figure 4 reveals a noteworthy finding about the distribution of opportunistic fungus among the schools. This discovery is supported by a P-value of 0.0002, which falls far below the predetermined threshold of 0.05 for statistical significance. This implies that there is considerable variation in the environmental circumstances or factors that affect the occurrence of opportunistic fungi among different institutions, which in turn affects the extent of exposure experienced by students and staff to these specific types of fungi. In contrast, there were no statistically significant differences seen in the percentage of harmful fungi among the various schools(P-value = 0.173) , suggesting a very consistent distribution of pathogenic fungi across the educational environments. The observed uniformity implies that the factors that contribute to the occurrence of pathogenic fungi may exhibit greater consistency across various educational institutions in comparison to the ones that influence opportunistic fungi. The differentiation between opportunistic and pathogenic fungi holds significant importance within the realm of public health. Individuals with damaged immune systems are especially at danger from opportunistic fungi, which can cause infections when the host's defenses are reduced. The considerable disparity in their occurrence implies that certain educational institutions may possess settings that are more favorable for the development and spread of these fungi, hence requiring focused actions to alleviate these hazards. Conversely, pathogenic fungi have the ability to induce illnesses in both persons with good health and those with weakened immune systems, although they seem to be more uniformly spread throughout the schools. The consistent distribution of these fungi may be attributed to shared characteristics in building design, maintenance procedures, or air quality management among schools that do not specifically promote or hinder their growth. The data indicates a diverse dispersion of pathogenic fungus throughout different departments, with significant proportions found in the classrooms and bathrooms of Schools 2 and 4. In contrast, School 3 does not exhibit any presence of pathogenic fungi in any department. School 1 displays pathogenic fungus exclusively within the classroom. The figure emphasizes a crucial feature, namely the statistical analysis results, which demonstrate that there are no statistically significant differences at a significance level of 0.05 (with a reported p-value of 0.560) among the various departments inside and across the schools. From a statistical perspective, the distribution of pathogenic fungi among the departments of each school does not reach a statistically significant level. This indicates that the risk of being exposed to pathogenic fungi is relatively consistent across the different school environments that were evaluated. The existence of disease-causing fungi in specific settings, specifically classrooms and toilets, highlights the significance of implementing focused cleaning and maintenance measures in these spaces to reduce the likelihood of fungal contact. Classrooms, as the key locations for student engagement, and toilets, which may possess elevated moisture levels that promote fungal proliferation, necessitate specific consideration in endeavors to uphold optimal indoor air quality. The absence of substantial variations in fungal distribution implies that the environmental factors that promote the establishment of harmful fungus may be rather consistent throughout various departments and schools. Nevertheless, the particular occurrence in educational settings such as classrooms and restrooms underscore the necessity for personalized evaluations and interventions aimed at tackling the specific environmental circumstances or maintenance procedures that contribute to these observations. Figure 5 underscores the imperative of implementing complete air quality management methods within educational institutions, which encompass the consistent monitoring of fungal contamination in all locations frequented by students and staff. This methodology has the potential to promote a secure and conducive educational setting, hence reducing the likelihood of encountering pathogenic fungus. The variations in fungal populations and types among different schools and sections can be linked to the level of environmental hygiene in these schools. The issues at hand include inadequate management, substandard hygiene, high visitor density, overcrowding of students, adverse weather conditions (including air and dust levels, temperature and humidity), disinfection procedures, school design, school site, and safety and security measures. As a result, there is an impact on the incidence of illnesses among these educational institutions (Jaffal et al. 1997; WHO, 2002).

CONCLUSION

The present study successfully detected a large presence of both pathogenic and opportunistic fungi in educational buildings in Sana'a City, Yemen, based on a comprehensive investigation of airborne pathogenic and opportunistic fungi. The examination unveiled a heterogeneous fungal assemblage, wherein Aspergillus emerged as the predominant genus, suggesting a broad spectrum of fungal species inside educational settings that may have implications for the well-being of students and staff. So, this study highlights the significant significance of upholding elevated indoor air quality standards within educational institutions in order to protect the well-being of individuals occupying these spaces. The notable disparity in fungal contamination levels among the schools indicates that environmental conditions, maintenance

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procedures, and the structural integrity of the buildings are pivotal factors in the spread of fungal species. The prevalence of opportunistic fungus, specifically, underscores the necessity for focused measures in educational institutions to reduce exposure, particularly among those with compromised immune systems who are more susceptible to infections. Moreover, the even dispersion of harmful fungus across educational institutions suggests a widespread and pervasive hazard, hence requiring the implementation of comprehensive techniques for managing air quality.

RECOMMENDATION

1. Establish a system of regular monitoring and assessment in schools to track the concentrations of airborne fungus. This will allow for prompt detection and reduction of any health hazards.

2. Implement environmental control measures to improve cleaning and maintenance routines in order to decrease the spread of fungi, especially in locations that have been designated as high-risk, such as classrooms and bathrooms. This encompasses enhancing airflow, regulating humidity levels, and implementing efficient fungal disinfection methods.

3. Enhancements to the infrastructure: To mitigate the proliferation of fungal growth, it is imperative to undertake renovations and repairs that specifically target structural deficiencies, including but not limited to water leaks, suboptimal ventilation, and insufficient sunlight exposure.

4. Education on Health and Safety: Provide comprehensive instruction to school officials, teachers, and maintenance personnel regarding the potential health hazards linked to fungal exposure, as well as the optimal strategies for upholding a hygienic indoor environment.

5. Policy Development and Implementation: Promote the establishment and implementation of nationwide and regional regulations regarding indoor air quality in educational environments, drawing from the results of this and comparable research, to guarantee a uniform approach to managing air quality in schools.

6. Promote continued investigation into the interaction between airborne fungus and educational settings, as well as the efficacy of various intervention approaches, in order to consistently enhance indoor air quality requirements. By following these guidelines, educational establishments can enhance their ability to regulate indoor air quality and safeguard the physical and mental health of its residents, so cultivating a safer and more favorable educational setting.

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