

A survey of outdoor and indoor airborne fungal spora in the Redemption City, Ogun State, south-western Nigeria

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Abstract The concentration and biodiversity of airborne fungi of the Redemption City, an immense campground for Christian faithful and the temporary site of the Redeemer's University in south-western Nigeria, was studied between February and May 2011 using the culture plate method. The study was undertaken to assess the concentrations of fungal spores and their health implication in this ever-busy environment. Fifteen different sites classified as closed or open were selected. During the experiment, a total of 228 colonies were counted, and 29 fungal species belonging to 26 genera were isolated which include the following: *Aspergillus flavus*, *Aspergillus niger*, *Bipolaris* spp., *Chrysosporium* spp., *Cladosporium* spp., *Coniothyrium corda*, *Curvularia* spp., *Diplodia* spp., *Fusarium* spp., *Gliocladium* spp., *Monilia* spp., *Mucor* spp., *Mucor plumbeus*, *Penicillium* spp., *Phycomyces* spp., *Phytophthora* spp., *Pilobolus* spp., *Pyrenochaeta* spp., *Rhizopus stolonifer*, *Torula* spp., *Trichoderma* spp. and *Trichophyton* spp. The most frequently occurring fungi were *A. niger*, *C. corda* and *M. plumbeus*, while the least recorded were *Torula* and *Trichophyton* species. Majority of the fungi isolated are known allergens; they could also be opportunistic causing various diseases in man. There

is therefore a dire need for good sanitation practices within the studied areas of the camp.

Keywords Airborne fungi · Respiratory allergy · Indoor · Outdoor · Redemption City · South-western Nigeria

1 Introduction and literature review

Fungi are a fascinating group of organisms associated directly or indirectly with everyday life of mankind. In nature fungi grow in diverse habitats in diverse ways (Sharma 2005). The non-living particles on which fungi can grow include woods and wood products, for example, furniture, papers or books, and leather and its products like shoes and bags. Some fungi have the ability to degrade lignin and grow inside solid wood. Likewise, the air serves as a means of dispersal for almost all fungi (Ingold and Hudson 1993). Among the wide variety of biological particles present in the atmosphere, there are significant numbers of fungal spores (Gregory 1973). Fungi live as saprophytes on organic material or as parasites (mainly plant pathogens), so the majority of fungal spores in the air outdoors come from farms, forest stands and decomposing plant matter. Fungal spores are a normal and major component of indoor as well as outdoor air.

Although most fungi have periods of the year when their spores are more prevalent than others, some can be found virtually all year round. Concentration of

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fungal spores in outdoor environments is usually high, especially during the rainy season. Although many spore types are washed from the atmosphere during rainfall, other spore types only occur in rainy weather. The air is abundant of fungal spores although it is not a good medium for growth unlike the soil, water, surfaces of living organisms and non-living materials (Deacon 1980). Studies that have been carried out in various parts of the world confirm that the air in many indoor environments also contains spores (Aydogdu and Asan 2008; Adekunle 2001; Rainer et al. 2000; Singh et al. 1994, 1996; Vittal and Rasool 1995). The indoor locations sampled were hospital wards, children day care centres, eating places, agricultural farmlands, science laboratory, university libraries, upholstered furniture, showers, shower curtains, potted plants and the soil around potted plants.

Almost all spores are equipped with features that make them cope with the stresses of survival and dispersal. For effective dispersal spores need to have properties that are related to those of the dispersal agency, which may be fluid (air or water) or another organism (Darrel and Wilford 1976). The dispersal of fungal spores depends on some properties of the atmosphere and special features of the fungal spore. The major dispersal agent of fungal spores is wind, which can carry spores from long distances to a new area. Other dispersal agents include water, animals and even man.

Airborne fungal spores initiate human, animal and plant diseases. These fungi have many implications for the spread of human, animal and plant diseases, and for deterioration of stored products. Generally, three types of diseases are caused by fungal spores, and these are allergies, mycotoxicoses and mycoses. The significance of fungal spores in the air, in relation to allergy, was discussed by Hyde et al. (1956) and Sandhu et al. (1964) in reference to the air in Delhi, India. Furthermore, the incidence of respiratory diseases and exposure to allergens in indoor and outdoor environments has been widely recognized (Solomon 1975; Burge 1990; Lacey 1991; Gravesen 1994; Vijay et al. 1991; D'amato and Spieksma 1995; Hasnain et al. 1998). This is particularly important for children, adults and householders who spend more than 70 % of the day in these environments.

However, inhaled fungal spores can cause a number of conditions in humans with various consequences. Allergic responses, usually reactions to the proteins in the spore wall, can result in the development of a

running nose and eyes (allergic rhinitis), and asthma-like symptoms which are especially distressing in individuals who develop exaggerated allergic responses (hypersensitive or atopic individuals). Prolonged exposure to unusually large number of spores, often as a result of occupational circumstances, can result in the development of allergic alveolitis (Isaac 1996).

The fungal propagules in tropical areas include major allergens that can cause asthma and allergenic rhinitis (Ogunlana 1975; Bunnag et al. 1982; Adekunle 2001). According to studies, it has been reported that about 18 % of asthmatic patients, both adults and children, living in Mexico City, have positive skin reactivity to some fungi (Pedroza et al. 1984; Enriquez 1995).

It is interesting that while some fungal species are primary pathogens, invading the body through the respiratory tract, others are secondary pathogens invading in circumstances where the host is predisposed to infection. This could be as a result of the growth of some fungal species which would normally colonize dead and decaying material (saprophytic fungi) taking the opportunity to grow as pathogens such as *Aspergillus fumigatus* which is commonly found in dead organic material. Though it causes allergic reactions, it does not invade healthy tissues. Thus, it acts as a secondary pathogen affecting patients whose lung tissues had been previously diseased.

Numerous studies have been published on airborne fungal spores worldwide; these include Pakistan (Rao et al. 2009), Kuwait (Halwagy 1994), India (Chandra and Chanda 2000; Jothish and Nayar 2004; Adhikari et al. 2004a, b), Australia (Mitakakis and Guest 2001), Chile (Ibanez et al. 2001), Poland (Stepalska and Wolek 2005) and Spain (Mediavilla et al. 1997; Black et al. 2000; Munuera et al. 2001; La-sera et al. 2002; Sabariego et al. 2007). Unfortunately in Nigeria with its teeming population, these reports are few. The few published works from available literature include Ogunlana (1975); Agwu and Osibe (1992); Adekunle (2001); Agwu (2001); Agwu et al. (2004); Njokuocha and Osayi (2005); Njokuocha (2006); and Ade-onipekun and John (2011).

The main types of allergenic spores are *Alternaria*, *Aspergillus*, *Cladosporium* and *Penicillium*; *Cladosporium* is the most important in northern Europe and *Alternaria* in the Mediterranean area (D'amato et al. 1997). Little is known about the allergenic potential of the different types of spores and about the levels of exposure capable of provoking allergic responses

when they are encountered in outdoor environments (Levetin et al. 1995).

Zoppas et al. (2006) described the morphological identification of the following ascospores in air samples from a southern city in Brazil: *Leptosphaeria*, *Daldinia/Xylaria*, *Paraphaeosphaeria*, *Diatrypaceae*, *Pleospora* and undifferentiated ascospores. The following basidiospores were also identified: *Coprinus*, *Ganoderma*, *Agaricus*, *Agrocybe* and undifferentiated basidiospores. Ascospores and basidiospores made up about 50 % of the spore count, and this was for a research that was conducted for over 2 years.

Indoor, airborne fungal spores may represent a different mix of species. In the home environment, there are usually less spores than outdoors, and fewer species will be represented (Isaac 1996). Therefore, this study focuses on both the indoor and the outdoor environment. This is as a result of the type of ventilation system and the amount of air disturbance present in the office buildings such as air conditioning systems which markedly influence the species range, distribution of spores and the number present, thus encouraging sporulation of particular species.

There are different methods used in sampling for airborne spores and pollen. They include the culture plate method (Moustafa and Kamel 1976; Adhikari et al. 1999; Adekunle 2001; Aydogdu and Asan 2008; Rao et al. 2009), volumetric methodology sampling method (Abdel-Fattah and Swelim 1982; Diez et al. 2006; Calvo et al. 1980), the Anderson's Six Stage Volumetric sampler and Burkard Personal Slide Sampler (Cadman et al. 1997; Singh et al. 1994; Adhikari et al. 2004b). There are quite a few other methods other than these outlined techniques.

The present work is directed at the identification and quantification of airborne spores present on various sites on the Redemption Camp ground for a period of 4 months (February–May 2011), as the knowledge of the diversity and seasonal variation of the spectrum of fungal spores present in these sites would help in the prevention of certain allergies caused by these spores.

2 Materials and methods

2.1 Sampling sites

Samples were collected from fifteen selected sites within the Redemption Camp, Ogun State, south-west Nigeria

(Fig. 1). Each site was marked with a yellow flag. The Redemption Camp is the international headquarters of the Redeemed Christian Church of God (RCCG), a Nigeria-based Pentecostal ministry. The Redemption Camp is a bustling city with hundreds of residential houses, a full-fledged Bible College, a nursery, primary and a secondary school, along with hundreds of hostels and chalets, a 3-star hotel, an international guest house with many suites, office complexes of international standard, exquisite restaurants, massive auditoriums and the Redeemer's University (Ojoibukun 2010). The fifteen selected sites, of which five were open places (car parks, playing fields) while ten were indoors (staff offices, restaurants and auditoriums, classroom, and students hostels), are listed in Table 1 legend.

2.2 Sampling procedures

Samples were collected at each of the above-mentioned sites at 2-week intervals for 3 months (February–May 2011). Two Petri plates containing solidified agar were labelled according to each sampling site together with one control plate which was not exposed. On getting to each sampling site, the temperature and humidity readings were taken with an Omega -73 (OM-73) portable temp/humidity Reader. The Petri plates were then exposed for 10 min, so that spores of fungi in the air can fall and settle on the potato dextrose agar in the Petri plates. After exposure, the Petri dishes and the control plates were incubated for 2–3 days at room temperature to allow proper growth of the fungal colonies for identification. All the fungi growing on the plates were numbered and later subcultured onto new PDA plates while each growing colony had not grown into others. Pure cultures were stored on PDA slants in 14-ml McCartney bottles and stored in the refrigerator.

2.3 Fungal identification

To identify different fungi, microscopic examinations were carried out after different cultural characteristics such as colour of the fungal colony, the number of days before growth was observed and the growth texture were observed and used to identify the different fungi Ainsworth (1976). The descriptions of Talbot (1971); Barnett and Hunter (1972); Deacon (1980); Bryce (2000) and Brown (2007) such as surface and bottom colours, underside pigmentation,



Map of Nigeria with the triangle showing the Location of the Redemption City at KM 46/48 Lagos Ibadan Expressway

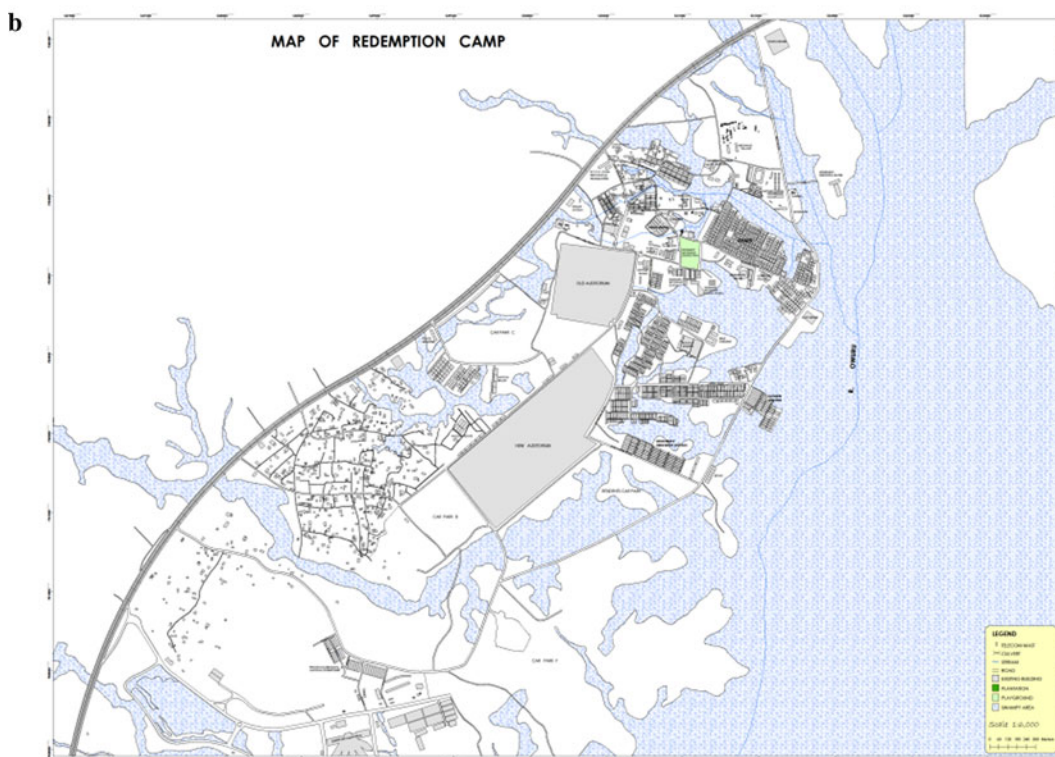


Fig. 1 **a** Map of Nigeria showing the location of the studied site. **b** Map of Redemption City not very clear

Table 1 Total and percentage occurrence of isolated fungi from the fifteen sampled sites in Redemption City

S/ no	Fungal genera	Site A (out)	Site B (ind)	Site C (ind)	Site D (ind)	Site E (out)	Site F (out)	Site G (out)	Site H (ind)	Site I (ind)	Site J (ind)	Site K (ind)	Site L (ind)	Site M (ind)	Site N (out)	Site O (ind)	Total	Percentage occurrence
1	<i>A. flavus</i>	1	—	1	1	1	—	—	1	—	—	—	—	—	2	2	9	3.95
2	<i>A. niger</i>	2	4	1	1	2	2	2	1	2	—	2	—	—	1	1	21	9.21
3	<i>Bipolaris maydis</i>	—	1	—	—	—	—	2	—	—	—	—	—	—	—	—	3	1.32
4	<i>Botrytis</i> spp.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	0.44
5	<i>Chaetomium</i> spp.	—	—	—	—	—	—	—	—	1	1	1	—	1	—	—	3	1.32
6	<i>Chrysosporium</i> spp.	—	—	—	1	—	—	1	—	—	—	1	—	—	1	—	4	1.75
7	<i>Cladosporium</i> spp.	1	1	—	—	—	1	—	4	1	—	—	—	—	1	1	10	4.38
8	<i>C. corda</i>	2	1	—	—	5	1	2	3	2	1	2	—	—	3	—	22	9.65
9	<i>C. lunata</i>	1	2	—	1	2	1	2	2	1	—	1	—	—	1	—	14	6.14
10	<i>Diplodia</i> spp.	—	1	—	—	—	—	1	—	—	—	—	1	—	—	1	4	1.75
11	<i>Eurotium</i> spp.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	0.44
12	<i>F. solani</i>	1	1	—	—	—	1	—	—	—	—	—	—	—	—	—	3	1.32
13	<i>Gliocladium</i> spp.	1	1	—	2	1	—	1	—	2	—	1	—	—	—	1	10	4.38
14	<i>Humicola</i> spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	0.44
15	<i>Monilia</i> spp.	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	0.44
16	<i>M. plumbeus</i>	3	2	1	5	2	1	—	1	1	—	—	1	—	—	—	17	7.46
17	<i>Mucor</i> spp.	1	1	2	2	1	1	1	—	—	2	3	4	—	4	2	21	9.21
18	<i>Penicillium</i> spp.	—	—	—	—	1	—	1	1	—	—	—	—	—	—	—	3	1.32
19	<i>Phoma</i> spp.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	2	0.88
20	<i>Phycomyces</i> spp.	—	—	—	1	3	—	—	2	1	—	—	—	—	—	—	7	3.07
21	<i>Phytophthora</i> spp.	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	2	0.88
22	<i>Pilobolus</i> spp.	—	—	—	—	2	—	—	—	—	—	—	—	—	1	—	3	1.32
23	<i>Pyrenochaeta</i> spp.	—	1	—	1	—	1	1	—	—	—	—	—	—	—	—	4	1.75
24	<i>R. stolonifer</i>	2	2	—	1	—	2	—	3	2	2	1	1	1	1	2	20	8.77

Table 1 continued

S/ no	Fungal genera	Site A (out)	Site B (ind)	Site C (ind)	Site D (ind)	Site E (out)	Site F (out)	Site G (out)	Site H (ind)	Site I (ind)	Site J (ind)	Site K (ind)	Site L (ind)	Site M (ind)	Site N (out)	Site O (ind)	Total	Percentage occurrence
25	<i>Rhizopus oryzae</i>			1	1	1							1				3	1.32
26	<i>S. balticus</i>												1				1	0.44
27	<i>Torula</i> spp.	-	-	-	-	-	-	-	1								1	0.44
28	<i>Trichoderma viride</i>	-	-	2	-	1	2	-	1	1	1	-	1	1	1	1	10	4.38
29	<i>Trichophyton spp.</i>	1	1	1	-	-	-	-	-	-	-	1	1	-	-	-	4	1.75
	Sterile colonies	2	1	1	3	1	2	1	2	2	2	0	1	2	2	1	23	10.09
	Total of fungal colonies	18	20	7	21	22	17	15	20	16	9	13	11	7	19	13	228	100 %
	Percentage site occurrence	7.9	8.77	3.07	9.21	9.65	7.46	6.58	8.77	7.02	3.95	5.7	4.82	3.07	8.33	5.7	100 %	

Site A = Redeemer High School field; Site B = King is Coming Church; Site C = Staff Offices; Site D = Old Auditorium; Site E = Car Park C open field; Site F = Congress ground Surrounding; Site G = Canaan land open area; Site H = Hostel Conoil Restaurant; Site I = Moses Hostel; Site J = Cafeteria; Site K = Queen Esther Hostel; Site L = Banquet Hall Restaurant; Site M = Redeemer's Pry. School classroom; Site N = Redeemer's Pry. School Field; and Site O = Gate Conoil Restaurant

Ind = indoor site, Out = outdoor site

Table 2 Total and percentage occurrences of isolated fungi from the indoor and outdoor sites in Redemption City

S/ no	Indoor sites													Outdoor sites						
	Fungal genera													Fungal genera						
	Site B	Site C	Site D	Site H	Site I	Site J	Site K	Site L	Site M	Site O	Total occurrences	Percentage occurrences	Fungal genera	Site A	Site E	Site F	Site G	Site N	Total occurrences	Percentage occurrences
1	<i>A. flavus</i>	1	1	1	1	1	1	1	1	2	5	3.65	<i>A. flavus</i>	1	1	1	1	2	4	4.39
2	<i>A. niger</i>	4	1	1	1	2	2	1	1	1	12	8.76	<i>A. niger</i>	2	2	2	2	1	9	9.89
3	<i>Bipolaris</i> sp.	1	1	1	1	1	1	1	1	1	1	0.73	<i>Bipolaris</i> sp.	1	1	1	1	1	2	2.2
4	<i>Botrytis</i> sp.	1	1	1	1	1	1	1	1	1	1	0.73	<i>Botrytis</i> sp.	1	1	1	1	1	0	NA
5	<i>Chaetomium</i> sp.	1	1	1	1	1	1	1	1	1	3	2.19	<i>Chaetomium</i> sp.	1	1	1	1	1	0	NA
6	<i>Chrysosporium</i> sp.	1	1	1	1	1	1	1	1	1	2	1.46	<i>Chrysosporium</i> sp.	1	1	1	1	1	2	2.2
7	<i>Cladosporium</i> sp.	1	1	1	1	1	1	1	1	1	7	5.11	<i>Cladosporium</i> sp.	1	1	1	1	1	3	3.3
8	<i>C. corda</i>	1	1	1	1	1	1	1	1	1	9	6.57	<i>C. corda</i>	2	5	1	2	3	13	14.28
9	<i>C. lunata</i>	2	1	1	1	1	1	1	1	1	7	5.11	<i>C. lunata</i>	1	2	1	2	1	7	7.69
10	<i>Diplodia</i> sp.	1	1	1	1	1	1	1	1	1	3	2.19	<i>Diplodia</i> sp.	1	1	1	1	1	1	1.1
11	<i>Eurotium</i> sp.	1	1	1	1	1	1	1	1	1	1	0.73	<i>Eurotium</i> sp.	1	1	1	1	1	0	NA
12	<i>F. solani</i>	1	1	1	1	1	1	1	1	1	1	0.73	<i>F. solani</i>	1	1	1	1	1	2	2.2
13	<i>Glilocladium</i> sp.	1	1	1	1	1	1	1	1	1	7	5.11	<i>Glilocladium</i> sp.	1	1	1	1	1	3	3.3
14	<i>Humicola</i> sp.	1	1	1	1	1	1	1	1	1	0	NA	<i>Humicola</i> sp.	1	1	1	1	1	1	1.1
15	<i>Monilia</i> sp.	1	1	1	1	1	1	1	1	1	0	NA	<i>Monilia</i> sp.	1	1	1	1	1	1	1.1
16	<i>M. plumbeus</i>	2	1	1	1	1	1	1	1	1	11	8.03	<i>M. plumbeus</i>	3	2	1	1	1	6	6.59
17	<i>Mucor</i> spp.	1	1	1	1	1	1	1	1	1	14	10.22	<i>Mucor</i> spp.	1	1	1	1	1	7	7.69
18	<i>Penicillium</i> spp.	1	1	1	1	1	1	1	1	1	1	0.73	<i>Penicillium</i> spp.	1	1	1	1	1	2	2.2
19	<i>Phoma</i> spp.	1	1	1	1	1	1	1	1	1	2	1.46	<i>Phoma</i> spp.	1	1	1	1	1	0	NA
20	<i>Phycomyces</i> spp.	1	1	1	1	1	1	1	1	1	4	2.92	<i>Phycomyces</i> spp.	1	1	1	1	1	3	3.3
21	<i>Phytophthora</i> spp.	1	1	1	1	1	1	1	1	1	1	0.73	<i>Phytophthora</i> spp.	1	1	1	1	1	1	1.1
22	<i>Pilobolus</i> spp.	1	1	1	1	1	1	1	1	1	0	NA	<i>Pilobolus</i> spp.	1	1	1	1	1	3	3.3
23	<i>Pyrenochaeta</i> spp.	1	1	1	1	1	1	1	1	1	2	1.46	<i>Pyrenochaeta</i> spp.	1	1	1	1	1	2	2.2
24	<i>R. stolonifer</i>	2	1	1	1	1	1	1	1	1	15	10.95	<i>R. stolonifer</i>	2	1	1	1	1	5	5.49
25	<i>Rhizopus oryzae</i>	1	1	1	1	1	1	1	1	1	2	1.46	<i>Rhizopus oryzae</i>	1	1	1	1	1	1	1.1
26	<i>S. bairdii</i>	1	1	1	1	1	1	1	1	1	1	0.73	<i>S. bairdii</i>	1	1	1	1	1	0	NA
27	<i>Torula</i> spp.	1	1	1	1	1	1	1	1	1	1	0.73	<i>Torula</i> spp.	1	1	1	1	1	0	NA
28	<i>T. viride</i>	1	1	1	1	1	1	1	1	1	6	4.38	<i>T. viride</i>	1	1	1	1	1	4	4.39
29	<i>Trichophyton</i> spp.	1	1	1	1	1	1	1	1	1	3	2.19	<i>Trichophyton</i> spp.	1	1	1	1	1	1	1.1

Table 2 continued

S/ no	Indoor sites													Outdoor sites									
	Fungal genera	Site B	Site C	Site D	Site H	Site I	Site J	Site K	Site L	Site M	Site O	Total	Percentage occurrences	Fungal genera	Site A	Site E	Site F	Site G	Site N	Total	Percentage occurrences		
Sterile colonies	1	1	3	2	2	2	0	1	2	1	15	10.95		Sterile colonies	2	1	2	1	2	8	8.79		
Total	20	7	21	20	16	9	13	11	7	13	137	100		Total	18	22	17	15	19	91	100		
Percentage per site	14.59	5.11	15.33	14.6	11.68	6.57	9.49	8.03	5.11	9.49	100			Percentage occurrence	19.78	24.18	18.68	16.48	20.88	100			

Indoor sites: Site B = King is Coming Church; Site C = Staff Offices; Site D = Old Auditorium; Site H = Hostel Conoil Restaurant; Site I = Moses Hostel; Site J = Cafeteria; Site K = Queen Esther Hostel; Site L = Banquet Hall Restaurant; Site M = Redeemer's Pry. School classroom; and Site O = Gate Conoil Restaurant. Outdoor sites: Site A = Redeemer High School field; Site E = Car Park C open field; Site F = Congress ground Surrounding; Site G = Canaan land open area; and Site N = Redeemer's Pry. School Field

colony elevation, presence of spores, shape and type of spores, presence of septa, hyphal mass and structure were important phenotypic characteristics used in the identification of fungi together with nature of colonies (which includes the following: wooly, fluffy, powdery, cottony, fuzzy and slimy), were all used to compare each fungal morphological and cultural characteristics. Photomicrographs of the isolated fungal species were taken. Prof. A. Adekunle of the Department of Botany, University of Lagos, did the authentication of the different fungi. The stock cultures of the various isolates were preserved at the Redeemers University Biology Laboratory.

3 Results

The total and percentage occurrences of isolated fungal species from the fifteen sampled sites in Redemption City the in 3-month period are displayed in Table 1, while the total and percentage occurrences of these isolated fungi in the indoor and outdoor sites are shown in Table 2. During the experiment, a total of twenty-nine fungal species belonging to twenty-six genera were isolated from all the sites sampled. While some occurred almost in all the sample sites, a few were encountered in one or two sites only (Table 2). Some fungal colonies could not be identified because they failed to sporulate within the study period. Hence, they were listed as sterile colonies. Again, no growth was observed in the control plates.

Aspergillus, *Mucor* and *Rhizopus* had two species each, while the other twenty-three genera had one species each. There was a marked trend in the distribution of these fungi as no species was found in all the sites. However, the most common and frequently encountered fungal species were species of *Mucor*, *Aspergillus*, *Rhizopus* and *Coniothyrium*, each with total counts of 38, 30, 23 and 22 (Tables 1, 2). However, *Gliocladium*, *Cladosporium* and *Trichoderma* species had ten counts each. Of all the fungal genera present, species of *Aspergillus* were the most prevalent as they occurred in almost all the sampled sites. *Aspergillus niger* was present in twelve out of fifteen sites, while *Aspergillus flavus* occurred in seven out of fifteen sites. Furthermore, *Rhizopus stolonifer* occurred twelve times, while *Curvularia* spp., *Mucor* spp. and *Coniothyrium* spp. all occurred ten times and *Mucor plumbeus* occurred nine times. The least

occurring fungal genera were species of *Scopulariopsis bainiers*, *Monilia* spp., *Torula* spp., *Humicola* spp. and *Phoma* spp, which all occurred once (Table 1).

3.1 Comparative analysis of the sampled indoor and outdoor sites

A critical analysis of the data from the indoor and outdoor sites (Table 2), the latter being more in number, showed that more fungi were isolated from the indoor sites (137) as compared to those (91) from

the outdoor sites (Figs. 1, 2). Again, more species were isolated from the indoor sites though they were more in number compared to the outdoor sites (Figs. 3, 4). Such species as *S. bainiers*, *Torula* spp., *Phoma* spp., *Eurotium* spp. and *Botrytis* spp. were not encountered in the outdoor sites (Fig. 4). On the contrary, *Humicola* spp., *Pilobolus* spp. and *Monilia* spp. were not isolated from the indoor sites (Fig. 3). The presence of *Pilobolus* spp., which is associated with animal dung, could have occurred due to the feeding of horses and donkeys in these open fields.

Fig. 2 Percentage plot of total recovered fungi per studied site

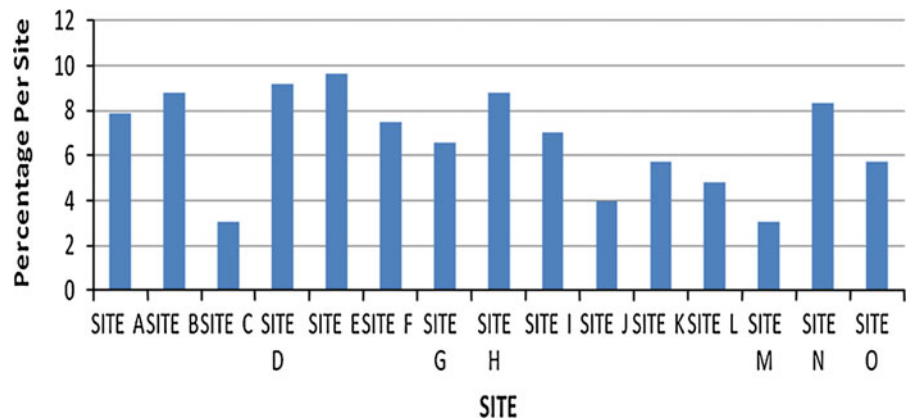


Fig. 3 Plot of percentage occurrence of recovered fungi per indoor site

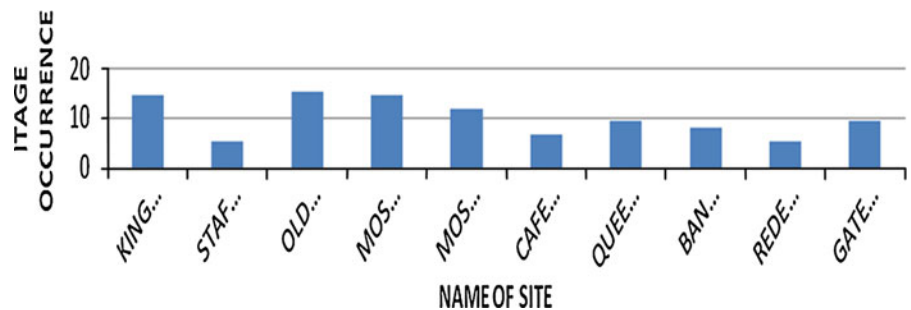
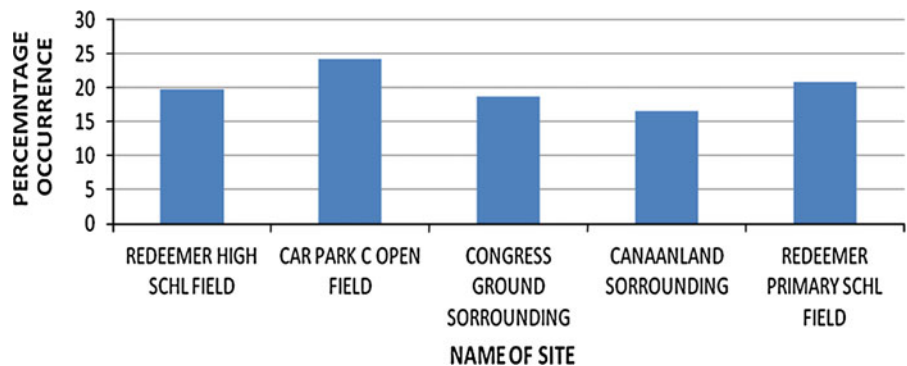


Fig. 4 Plot of percentage occurrence of the recovered fungi per outdoor site



3.2 Comparing the temperature and humidity values for the sampled indoor and outdoor sites

The temperature readings for the different sampling days differed ranging from 18 °C on cool days and air-conditioned sites to 28 °C on the drier and hotter days (Table 3). The temperatures in the staff offices, restaurants and some of the auditoriums were possibly affected by the presence of air conditioners which reduced their temperatures compared to the outside. Again, the humidity of the indoor sites was lower compared to those of the outdoor sites in most cases. On the 15th and 24th of April 2011, days following rainfall on the 13 and 23, respectively, the temperatures were generally low and the humidity high in most of the sites (Table 3). With all these conditions, the indoor sites especially the old auditorium, the Hostel Conoil restaurant and Christ is coming church auditoriums recorded the highest recoveries of fungi coupled with the outdoor car park C open field, Redeemer's High school field and Redeemer's primary school field (Fig. 2). Furthermore, the least recoveries were made in staff offices, Redeemer's Primary school classroom and the cafeteria, suggesting that these places are regularly cleaned than most of the other sites. The different fungi must be well adapted to survive in these environments irrespective of varying temperature and humidity regimes.

4 Discussion

This study revealed that a great variety of fungal spores constitute the airborne spora of the Redemption Camp. The isolated fungi varied from one site to the other possibly due to the availability of their selective hosts or substrates in such environments together with prevailing environmental factors. During the survey period, two hundred and twenty-eight colonies were counted from all the sampled sites. The sporulating fungal species were identified with some occurring in majority of the sites. Species of *Aspergillus* were the most prevalent as they occurred in almost all the sampled sites. *A. niger* was present in twelve and *A. flavus* in seven out of the fifteen sites. Furthermore, *R. stolonifer* occurred twelve times, while *Curvularia* spp., *Mucor* spp., *Gliocladium* spp., *Corniothyrium* spp. and all *Cladosporium* spp. occurred ten times and

M. plumbeus occurred nine times. The least occurring fungal genera were species of *S. bainiers*, *Monilia* spp., *Torula* spp., *Humicola* spp. and *Phoma* spp. The total counts of isolated fungi closely followed this trend. *Mucor* species had the highest counts, followed successively by *Aspergillus* spp., *Corniothyrium* spp., *Curvularia* spp., *Gliocladium* spp. and *Cladosporium* spp., which all had total counts of ten and above. The other species were less frequent. Similar airborne and closely related fungal assemblages have been recorded by Njokuocha and Osayi (2005) and Agwu et al. (2004) in Nsukka, Nigeria; Adekunle (2001) in Lagos; Ogunlana (1975) from Ibadan, Nigeria; Adhikari et al. (2004a, b) and Singh et al. (1994) in India; Sneller and Roby (1979) and Lumpkins et al. (1973) in California, USA; Rao et al. (2009) in Karachi, Pakistan; Sen and Asan (2009) and Aydogdu and Asan (2008) in Turkey; and Calvo et al. (1980) and De Ana et al. (2006) in Barcelona, Spain.

Some of these fungi isolated are known allergens, while others could be opportunistic in nature causing various human diseases. Fungal spores had been considered to be correlated with air pollution, and also they had been proposed to be a cause of adverse health effects on humans, animals and plants (Shelton et al. 2002). Some of the species mentioned above are pathogenic and have serious health implications in man which include lung infections, runny nose and eyes (allergic rhinitis) and asthma-like symptoms which are especially distressing in hypersensitive or atopic individuals. Also, these extremely tiny fungal spores cause allergic reactions in susceptible people and respiratory irritation in non-allergic people. As a result, inhalation of fungal spores such as *Aspergillus*, *Mucor*, *Penicillium*, *Curvularia*, *Rhizopus* and *Cladosporium* by highly susceptible people can have fatal consequences. These pathogenic spores are discussed as follows:

Kurup and Kumar (1991) and Singh et al. (1994) had posited that the inhalation of fungal spores could produce upper and lower respiratory tract symptoms together with immunosuppressive patients especially leukaemic and renal transplant patients.

Originally thought to be solely a pathogen of plants, *Curvularia* has been described as a pathogen of humans and animals in the last half-century, causing respiratory tract, cutaneous and corneal infections. Carter and Boudreaux (2004) had reported a fatal case of cerebral *Curvularia* infection caused by *C. lunata* in

Table 3 Temperature and humidity readings during the days of sampling

Dates	Parameter	Site A (out)	Site B (ind)	Site C (ind)	Site D (ind)	Site E (out)	Site F (out)	Site G (out)	Site H (ind)	Site I (ind)	Site J (ind)	Site K (ind)	Site L (ind)	Site M (ind)	Site N (out)	Site O (ind)
16/2/ 2011	Temp	26 °C	29 °C	20 °C	26 °C	28 °C	28 °C	27 °C	29 °C	22 °C	26 °C	20 °C	28 °C	26 °C	24 °C	28 °C
	Humidity	20	18	18	22	32	30	32	24	20	19	18	20	20	20	22
3/3/ 2011	Temp	24 °C	26 °C	18 °C	22 °C	26 °C	24 °C	22 °C	24 °C	20 °C	22 °C	22 °C	26 °C	20 °C	18 °C	20 °C
	Humidity	36	18	18	26	37	32	20	24	19	19	24	18	32	35	20
18/3/ 2011	Temp	20 °C	26 °C	20 °C	25 °C	27 °C	22 °C	23 °C	26 °C	20 °C	22 °C	20 °C	26 °C	20 °C	18 °C	20 °C
	Humidity	34	28	14	20	36	32	20	20	19	19	24	19	32	35	20
25/3/ 2011	Temp	23 °C	26 °C	22 °C	22 °C	24 °C	24 °C	26 °C	24 °C	20 °C	22 °C	22 °C	26 °C	20 °C	18 °C	20 °C
	Humidity	36	18	16	18	35	36	20	18	19	19	24	18	32	35	20
6/4/ 2011	Temp	28 °C	26 °C	18 °C	26 °C	28 °C	28 °C	20 °C	26 °C	20 °C	22 °C	22 °C	26 °C	22 °C	20 °C	23 °C
	Humidity	36	16	14	20	40	34	20	19	19	19	24	20	32	35	22
15/4/ 2011	Temp	22 °C	24 °C	24 °C	24 °C	24 °C	24 °C	25 °C	26 °C	20 °C	22 °C	22 °C	26 °C	20 °C	24 °C	20 °C
	Humidity	39	20	16	18	42	36	20	24	19	19	24	19	32	34	21
25/4/ 2011	Temp	20 °C	24 °C	22 °C	24 °C	26 °C	26 °C	24 °C	28 °C	20 °C	22 °C	22 °C	26 °C	20 °C	18 °C	20 °C
	Humidity	36	16	18	16	37	30	20	21	19	19	24	19	32	32	20
9/5/ 2011	Temp	24 °C	22 °C	22 °C	24 °C	24 °C	26 °C	24 °C	26 °C	20 °C	22 °C	22 °C	26 °C	20 °C	18 °C	24 °C
	Humidity	40	18	18	26	36	32	20	20	19	19	24	22	32	35	20

which there was no known history of immune compromise or prior respiratory tract or sinus infection in the patient. Again, Bakerspigel et al. (1981) had isolated a strain of the soil-borne fungus *Phoma eupyrena* from the skin of an 18-month-old boy who had a crusting, erythematous, perioral eruption of 1-month duration.

Cladosporium species are quite allergenic; they carry mycotoxins in their spores and in some cases produce volatile metabolites which cause hazards to human health (Miller 1998). Also, *Cladosporium* exposure may inhibit the response of T_H2 lymphocytes. T_H2 cells tend to stimulate antibody responses in general by promoting interleukins which promote B cell maturation and humoral cell responses. The T_H2 cells also produce cytokines such as IL-4, IL-5, IL-6, IL-10 and IL-13 which defends against helminth parasites. Likewise, *Cladosporium* exposure inhibits the function of the white blood cells, that is, blocking dangerous microbes or foreign organisms from invading the body cells (Wakefield 2006).

Aspergillus flavus is pathogenic to several animal and plant species, including humans and domestic animals. Growth of the fungus on a food source often leads to contamination with aflatoxin, a toxic and carcinogenic compound. *Aspergillus flavus* is the second leading cause of aspergillosis in humans. It causes aspergillosis in weak human lungs or respiratory tract (Robbins et al. 1995), and as a result, patients infected with *A. flavus* often have reduced or compromised immune systems.

Furthermore, though *Mucor* and *Rhizopus* species are not known to be allergenic, they could also be opportunistic (Ekundayo 1986). The presence of greater number of these fungal species in indoor environments such as eateries, hostels and auditoriums could cause serious health hazards to users or residents of such environments. *Mucor*, for instance, has been implicated to cause nasal sinuses and lung and gastrointestinal tract infection due to inhaling or ingestion of the spores in dust or air. *Rhizopus* on the other hand causes opportunistic infections in neutropenic persons and ketoacidic diabetes (Adekunle 2001). This is due to the fact that the mode of entry of these spores is through inhalation of dust particles contaminated with the fungi.

The presence of *Penicillium* species in the Redemption Camp is of great concern as they are considered to be potential toxin producers. This suggests that the

mycotoxins produced may be involved in producing the lung diseases that occur from the inhalation of organic dust. Also, individuals exposed to spores of *Penicillium* are more likely to test positive to a skin-prick test (Wakefield 2006).

Fusarium species are quite allergenic, and as a result, they may affect the immunological response of the lung tissues or cause other hazards to human health (Gerberick 1984). Also, there had been reports of *Fusarium* spp. being the causative agent of fungal nail infection and mycotic keratitis (Al-Doory 1980).

Bearing in mind that there were ten indoor and five outdoor sites studied in the Redemption Camp (Table 2), a critical analysis of the data from the two sites has highlighted that more fungi were isolated from the indoor sites (137) as compared to those (91) from the outdoor sites (Fig. 2). Such species as *S. bairdii*, *Torula* spp., *Phoma* spp., *Eurotium* spp. and *Botrytis* spp. were not encountered in the outdoor sites. On the contrary, *Humicola* spp., *Pilobolus* spp. and *Monilia* spp. were not isolated from the indoor sites. The indoor assemblage was dominated successively by *R. stolonifer*, *Mucor* spp., *A. niger* and *Corniothyrium corda* (Fig. 5), while *C. corda*, *Mucor* spp., *A. niger* and *Curvularia* spp. dominated the outdoor flora (Fig. 6). These results concur with those of Nayar et al. (2007), who noted no large difference in the concentrations and types of fungal spores between the indoor and outdoor environments in Kerala, India, with 26 spore types found to be present indoors and 27 types outdoors; of these, 22 were common to both the environments. *Aspergillus/Penicillium*, *Cladosporium*, other basidiospores and ascospores were the dominant spore types. However, with the exception of *Alternaria*, *Botrytis*, *Cladosporium* and *Torula*, which were isolated in the present study, Kasprzyk and Worek (2006) also encountered *Epicrococcum*, *Ganoderma*, *Pithomyces*, *Polythrincium*, *Stemphylium* and *Drechslera* in their survey of airborne fungal spores in urban and rural environments in Poland. As mentioned earlier, the dung of the horses feeding in the open fields could have encouraged the growth of *Pilobolus* spp. These observations differ from the reports of Sen and Asan (2009), who had worked in six different residential houses in Tekirdag city, Turkey, over a 12-month period counted a total of 4,205 microfungi colonies of which 1,790 were from indoor air and 2,415 from outdoor air. Their assemblage slightly resembled those from this study in having *A. niger*,

Fig. 5 Plot of percentage occurrence of the indoor flora

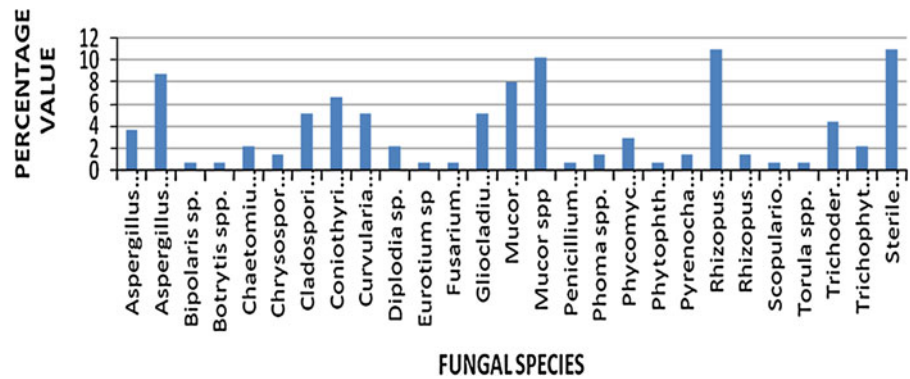
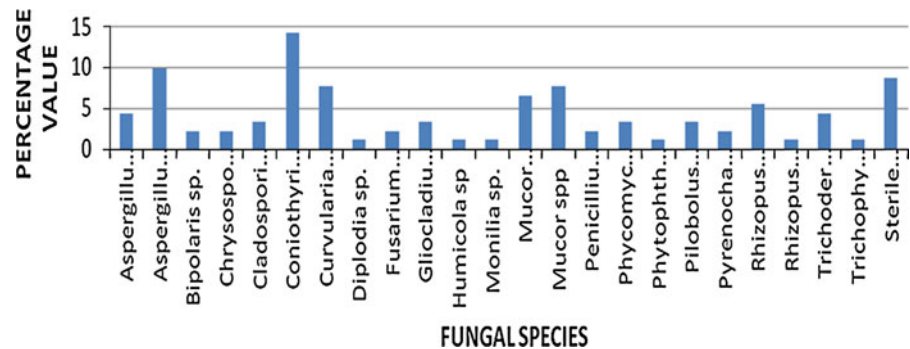


Fig. 6 Plot of percentage occurrence of the indoor flora



Cladosporium cladosporioides, *Alternaria* spp. and *Penicillium* spp., though here the most frequent were *Penicillium* spp., *Cladosporium* spp. and *Alternaria* spp. Again, while *Penicillium* spp. and *Cladosporium* spp. were the dominant genera of indoor air, *Alternaria* spp. and *Penicillium* spp. were isolated most frequently from outdoor air which is quite different from the present results.

The total fungi isolated from the four eating places (restaurants), two hostels and two sampled auditorium, revealed a very interesting trend. A total of fifty-three (53), forty-one (41) and twenty-nine (29) fungi were isolated from the eating places, auditoriums and hostels, respectively (Tables 1, 2). On the average, about fourteen were isolated from each of the eating places though the highest numbers were got from the Conoil restaurants and the least from the student's cafeteria; possibly, more care is taken by the authorities of the cafeteria to keep it clean. Again, the recovery from the old auditorium was one greater than that of the King is coming auditorium. This calls for caution on the sanitation units to work harder to keep these gathering places as clean as possible. Finally,

sixteen fungal isolates were got from the male hostel as against thirteen from the female. Perhaps, the surrounding vegetation especially around the male hostel could have contributed to this. Conclusively, these aforementioned places all need to be sanitized so as to be free of these fungal contaminants as possible. Collectively, the commonest fungi isolated from these places were *Mucor* spp., *R. stolonifer*, *A. niger*, *C. corda*, *Cladosporium* spp., *Gliocladium* spp. and *Curvularia lunata*, which have been implicated in allergic conditions.

It should be noted, however, that literature is less clear about the count that represents the danger level. Estimates range from 100 for *Alternaria* (Ebner and Haselwandter 1992) to 3,000 for *Cladosporium* (Gravesen 1979). To play safe, good sanitary conditions need to be maintained at all times before these fungi will accumulate to the danger levels.

Different workers have reported variations in the concentration of fungal spores with the time of day, season and weather. Ogunlana (1975) who worked on the fungal air spora in Ibadan, Nigeria, documented that the wet and dry seasons caused seasonal

periodicity in colony numbers. In this experiment, fungal spores occurred in higher concentrations during the dry season, but at the early stages of the rainy season, there was a gradual decline in the occurrence of fungal spores on the sites sampled. This was quite similar to Agwu et al. (2004) who reported that fewer spores were counted in the rainy season (May–October) as against the higher spore counts recorded during the dry season (November–April). Also, Huang et al. (2002) reported that airborne fungi were higher in winter than in other seasons in municipal landfill sites in southern Taiwan, and he ascribed it to the geographic characteristics of the sampling area. Singh et al. (1994) also reported the high density of *A. flavus* between the months of June and September in hospitals in Delhi, India, which they noted was of great concern to human health in the hospitals as *Aspergillus* species are a menace to some high-risk patients. It can therefore be assumed that the high spore count recorded during the dry season in this research project was probably due to low humidity, high temperature and wind speed which increased the rate of the spore release and dispersal in the atmosphere. Again, the onset of the rainy season could have washed down some of these spores suspended in the air.

Of all the fungal isolates that were obtained in this study, *Aspergillus* spp. were the most frequent, and this highest frequency of *Aspergillus* is in agreement with the earlier investigation by Al-Doory (1980) in Philadelphia, USA. He proposed that the commonest atmospheric fungi are the species of *Aspergillus*. Within the group of *Aspergillus*, *A. niger* had the highest isolation frequency. Also from this experiment, no new fungal species were isolated that had not been earlier reported by various workers all over the world. Likewise, there were slight differences in the fungal species isolated during the dry and the rainy seasons. During the dry season, *C. corda* and *Cladosporium* spp. appeared more frequently as against the dominance of *A. niger* and *A. flavus* after the onset of the rainy season.

Although many of the above-mentioned fungi are said to be pathogenic, their pathogenicity depends on their hosts. Some people are extremely allergic to the presence of particles in their environment. Those are the ones at risk of being affected by these fungi. As a result, an average healthy individual would not be affected.

5 Conclusion

Although this study was carried out in few areas in the Redemption Camp, it clearly revealed the concentration of different fungal species in the environment. Fungal spores are ubiquitous and quite dominant in the indoors as against the outdoor environments. These spores enter the enclosed areas through the normal air intake and sometimes through the ventilation air stream. As a result, adequate care must be taken to prevent the inhalation of fungal spores as prolonged exposure to unusually large numbers of spores, often as a result of occupational circumstances, can result in the development of allergic alveolitis (Susan 1996).

6 Recommendations

From the findings in this study, it is recommended that personal hygiene should be encouraged as this reduces the increasing effect of the fungal spores in overcrowded areas.

For the indoor environments, filtration provides primary defence against fungal spores entering a building ventilation system. Prefilters can be effective against most fungi, even when in the spore form, although for a higher degree of protection, high-efficiency particulate air (HEPA) filters are quite effective provided they are tightly installed and well maintained. Likewise, other materials that favour the growth of fungal spores such as old furniture should be removed while drain pans and water pans which breed spores must be treated as necessary with proper disinfectants. Also, the environment of both the open and the enclosed areas should be fumigated at least once every quarter to make them environmentally healthy for living.

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