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Status of airborne spores and pollen in a coir factory in Kerala, India

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Abstract The prevalence of airborne fungal spores and pollen grains in the indoor and outdoor environments of a coir factory in Thiruvananthapuram district of Kerala state, India was studied using the Burkard Personal Sampler and the Andersen 2-stage Sampler for 2 years (September 1997 to August 1999). The concentration of pollen grains was remarkably lower than that of fungal spores (ratio of 1:28). There was no large difference in the concentrations and types of fungal spores between the indoor and outdoor environments, 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. The total spore concentration was highest in February and lowest in September, and it was significantly higher in 1998–1999 than in 1997–1998. Twenty viable colony-forming types were isolated from inside the coir factory. The most dominant viable fungi isolated were *Penicillium citrinum*, *Aspergillus flavus* and *Aspergillus niger*. The total pollen concentration was higher in the outdoor environment of the coir factory than indoors, with 15 and 17 pollen types, respectively. Grass and *Cocos nucifera* pollen types were dominant. The dominant spore and pollen types trapped in the two environments of the coir factory are reportedly allergenic and, consequently, workers are at risk of catching respiratory/allergic diseases.

Key words Airborne spores and pollen · Coir factory · Indoor/outdoor environments · India

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1 Introduction

India is a leading country in the traditional manufacture of coir products. Kerala, a coastal state and a region of traditional coconut farming, located along the south-western corner of Peninsular India, accounts for more than 80% of India's manufactured coir (Rammohan 1999). Coir fibre is extracted from coconut husks after proper retting and spun into yarn by hand or electrically driven spinning wheels. About four lakhs (400,000) of people work in coir industry in Kerala, of whom more than 72% are engaged in coir spinning (Economic Review 1998). The inhalation of organic agricultural and industrial dusts is the principal cause of occupational respiratory allergy (Dutkiewicz 1997), consequently, it is not surprising that more than 68% of the coir workers in Kerala have complained of allergy and respiratory infections (Nair 1997).

Industrialization and urbanization have resulted in a significant increase in the number of biological particles in both indoor and outdoor environments (Pauli et al. 1989; Crook 1994; Singh and Gangal 2002). Aerobiological studies conducted in working environments such as dwelling places (Grant et al. 1989), poultry farms (Jothish and Nayar 2003), fibre board factories (Dutkiewicz et al. 2001), bakeries (Singh and Singh 1994), diary farms (Chakraborthy et al. 2000), markets (Kakde et al. 2001) and libraries (Tilak and Pillai 1988; Singh et al. 1995) have revealed that these environments are loaded with allergenic biopollutants at undesirable levels.

Given this backdrop, the aim of the present study was to assess the status of airborne fungal spores and pollen grains in the indoor and outdoor environments of a coir spinning factory.

2 Materials and methods

2.1 Study site

The study was conducted in a coir spinning factory under cooperative management, that is situated in Pachalloor, a coastal village, 10 km from Thiruvananthapuram, the capital city of Kerala. The factory building occupies an area of 320 m^2, in 0.2 acre compound and it is surrounded by 1.5-m-high brick walls. The factory building containing 60 electrically driven spinning machines (three rows of 20 machines) is sufficiently ventilated and covered with asbestos sheets. There are three cement water tanks ($3 \times 1.5 \times 1.5$ m) inside the walled compound, that are used for cleaning coconut fibre. The dominant vegetation is coconut. Other tree species found in the area are *Artocarpus, Casuarina, Eucalyptus, Terminalia, Peltophorum* and *Acacia*. Weeds and grasses are the main constituents of the ground flora.

Three types of operations are carried out in the factory: (1) hand winnowing of the dehusked fibre for separating the wastes; (2) mechanized winnowing of cleaned fibres; (3) spinning of winnowed fibres into coir. The first operation is carried out outside of the shed and, consequently, huge piles of coir wastes and pith accumulate in the compound. Large quantities of dusts are generated during the first and second operations, which find their way into the air. The second and third steps are carried out inside the factory by 65 female and three male factory employees. About 5 tonnes of coir are manufactured every month.

2.2 Sampling procedure

Air inside the factory building was sampled using the Burkard Personal Slide Sampler and the Andersen 2-stage Sampler at 2-week intervals for 2 years (from September 1997 to August 1999). The samplers were operated at a height of 1 m over the floor level and were exposed for 10 min each day between 9.30 a.m. and 12.30 p.m. when the coir spinning operations were at their maximum. Both samplers were operated simultaneously. Air inside the factory building was treated as indoor air and air 100 m away from the factory building was treated as outdoor air.

The Andersen Sampler samples 28.3 l of air per minute. Petri dishes containing 27 ml of Sabourard's agar supplemented with streptomycin were used for sampling. Exposed petri plates were subsequently incubated at 28°C for 3–4 days at which time colony-forming fungi were identified and counted. The results are expressed as mean numbers of colony-forming units per cubic metre of air (CFU m^{-3}) sampled.

The Burkard Sampler samples 10 l of air per minute. Slides smeared with basic fuchsin-stained glycerin jelly were used for the study. Exposed slides were scanned for fungal spores and pollen grains using 100×/40× objectives of a Nikon Labophot-2 microscope. The fungal spores and grains present were counted and identified, and expressed as mean numbers of spores/pollen grains per cubic metre air sampled, respectively.

2.3 Statistical analysis

Total concentrations of dominant types of pollen grains and spores in the years 1997–1998 and 1998–1999, respectively, and the concentrations of all spore and pollen types in the indoor and outdoor environments, respectively, of the coir factory in 1997–1999 were subjected to analysis of variance. The level of significance was set to $\alpha < 0.05$ and/or $\alpha < 0.01$.

3 Results

The numbers and types of fungal spores and pollen grains were recorded throughout the study period, September 1997 to August 1999. The concentrations of fungal spores inside and outside the factory were more or less the same during this period (indoor: $\bar{x}$ = 1196.5 spores m^{-3} air; outdoor: $\bar{x}$ = 1189.5 spores m^{-3} air). Twenty-seven spore types were identified outdoors and 26 spore types indoors, of which 22 were common to both environments. *Aspergillus*/*Penicillium*, *Cladosporium*, 'other basidiospores', ascospores and *Ganoderma* were the dominant spore types (Table 1). The total spore concentration was significantly higher in 1998–1999 than in 1997–1998 ($\alpha < 0.05$) (Table 3). Culture plate exposure showed a mean concentration of 100.43 CFU m^{-3} air during the study period. *Penicillium* and *Aspergillus* were the most dominant genera recorded. As expected, the total pollen concentration was higher in the outdoor environment ($\bar{x}$ = 40.64 pollen grains m^{-3}) than in the indoor environment ($\bar{x}$ = 28.56 pollen grains m^{-3} air) (Table 2). Fifteen pollen types were trapped inside and 17 pollen types outside the factory. Grass and *Cocos nucifera* pollen were the most dominant types.

3.1 Fungal spore concentration

In both environments, the total spore concentration reached a maximum in February (indoor: 880 spores m^{-3} air; outdoor: 2230 spores m^{-3} air) and a minimum in September (indoor: 860 spores m^{-3} air; outdoor: 700 spores m^{-3} air) (Fig. 1). *Aspergillus*/*Penicillium* was the chief constituent of the indoor air, with an isolation frequency of 34.37% of total airborne fungal spores, followed by *Cladosporium* (24.99%), 'other basidiospores' (18.65%) and ascospores (7.91%). *Cladosporium* was the main constitutent (33.89%) of the aeromycoflora in the outdoor air, followed by *Aspergillus*/*Penicillium* (24.72%), 'other basidiospores' (14.66%) and ascospores (5.76%). *Nigrospora* and *Ganoderma* constituted 3.87 and 2.98% of the aeromycoflora in the indoor air and 3.5 and 4.9% in the outdoor air, respectively (Table 1).

The concentration of *Aspergillus*/*Penicillium* was significantly higher ($\alpha < 0.01$) inside the factory ($\bar{x}$ = 411.25 spore m^{-3} air) than outside ($\bar{x}$ = 294 spores m^{-3} air). There were three distinct peaks in *Aspergillus*/*Penicillium* concentrations: June–August, October–November (both in the rainy seasons) and February (inside only; no distinct peak outside) (Fig. 2). However, the highest concentration inside the factory was recorded in July ($\bar{x}$ = 547.5 spores m^{-3} air) followed by November (522.5 spores m^{-3} air), and the highest concentration in the outdoor air was recorded in October (382.5 spores m^{-3} air) and August (380.5 spores m^{-3} air). In the outdoor area, the concentration of *Aspergillus*/*Penicillium* was significantly lower (α value < 0.01) in 1997–1998 (237.5 spores m^{-3} air) than in 1998–1999 (350.42 spores m^{-3} air (Table 3).

Cladosporium spores were present at a significantly higher concentration ($\alpha < 0.01$) in outdoor air ($\bar{x}$ = 403.17 spores m^{-3} air) than in indoor air ($\bar{x}$ = 288 spores m^{-3} air) (Table 1), with peak incidence occurring in February and the lowest concentration occurring during the rainy season (June–November) in both the environments (Fig. 2). There was no significant difference in the concentration of *Cladosporium* spores between 1997–1998 and 1998–1999 (Table 3). 'Other basidiospores' were abundant from September to November, with the maximum concentration of basidiospores in both the indoor ($\bar{x}$ = 452.5 spores m^{-3} air) and outdoor ($\bar{x}$ = 287.5 spores m^{-3} air) occurring in November and the minimum concentration in both environments occurring in April (indoor: 115 spores m^{-3} air; outdoor: 82.5 spores m^{-3} air) (Fig. 2). The peak concentrations of ascospores in both environments occurred in December (Fig. 2). The concentration of ascospores was higher in 1998–1999 (α value < 0.05) (indoor: 160.83 spores m^{-3} air; outdoor: 103.33 spores m^{-3} air) than in 1997–1998 (indoor: 28.33 spores m^{-3} air; outdoor: 33.75 spores m^{-3} air) (Table 3). Similarly, the maximum concentration of *Nigrospora* spores occurred in December in both environments (indoor: 95 spores m^{-3} air; outdoor: 82.5 spores m^{-3} air). The minimum concentrations were recorded in April and May for both environments (indoor: $\bar{x}$ = 15 spores m^{-3} air; outdoor: $\bar{x}$ = 20 spores m^{-3} air). The mean concentration of *Nigrospora* was significantly higher in 1998–1999 (indoor: 61.25 spores m^{-3} air; outdoor: 56.67 spores m^{-3} air) than in 1997–1998 (indoor: 31.25 spores m^{-3} air; outdoor: 26.67 spores m^{-3} air) (Table 3). The concentration of *Ganoderma* spores was comparatively lower in indoor air ($\bar{x}$ = 35.63 spores m^{-3} air) than in outdoor air ($\bar{x}$ = 58.33 spores m^{-3} air). The highest concentration of *Ganoderma* spores occurred in September inside the factory (62.5 spores m^{-3} air) and in June in the outside air (95 spores m^{-3}). The lowest count was

Table 1 Mean concentration, percentage and statistical significance of fungal spores in the indoor and outdoor environments of the coir factory from 1997 to 1999

Taxa	Indoor		Outdoor		Level of significance
	Number of spores m^{-3} air	Percentage	Number of spores m^{-3} air	Percentage	
Alternaria	1.67	0.14	4.79	0.4	–
Ascospores	94.58	7.91	68.54	5.76	–
Aspergillus/Penicillium	411.25	34.37	294	24.72	*
Bispora	3.96	0.33	7.08	0.60	–
Botryodiplodia	1.46	0.12	0.83	0.07	–
Choanephora	0.63	0.05	4.58	0.39	–
Cladosporium	299	24.99	403.17	33.89	*
Clasterosporium	0.21	0.02	0.83	0.07	–
Cordana	2.71	0.23	1.25	0.11	–
Corynespora	4.17	0.35	9.79	0.82	–
Curvularia	12.08	1.01	10.83	0.07	–
Dendryphiella	–	–	0.83	0.07	–
Dictyoarthrinium	1.67	0.14	0.21	0.07	–
Drechslera	5.63	0.47	11.25	0.95	–
Fusariella	–	–	0.21	0.02	–
Ganoderma	35.63	2.98	58.33	4.9	**
Leptosphaeria	1.25	0.1	4.58	0.39	–
Meliola	–	–	0.21	0.02	–
Nigrospora	46.25	3.87	41.67	3.50	–
'Other basidiospores'	223.17	18.65	174.42	14.66	–
Periconia	11.46	0.96	12.08	1.02	–
Pestalotiopsis	1.67	0.14	–	–	–
Pithomyces	9.38	0.78	10.42	0.88	–
Smuts/Rusts	10.00	0.84	13.54	1.14	–
Spegazzinia	0.21	0.02	–	–	–
Sporidesmium	0.21	0.02	–	–	–
Sporormia	–	–	0.21	0.02	–
Tetraploa	1.46	0.12	0.63	0.05	–
Torula	6.88	0.57	10.63	0.89	–
Trichoconis	1.04	0.09	0.63	0.05	–
Unidentified	8.96	0.75	43.96	3.70	–
Total spores	1196.50	–	1189.50	–	–

* Significant at $\alpha < 0.01$, ** Significant at $\alpha < 0.05$

recorded in December (10 spores m^{-3} air) and May (35 spores m^{-3} air) in the indoor and outdoor environments, respectively.

Other spore types, such as *Curvularia, Drechslera, Periconia, Pithomyces* and *Torula*, recorded in the coir factory environment occurred only irregularly (Table 1).

3.2 Fungal colony concentrations

Twenty fungal species belonging to eight genera were identified in the culture plates exposed to the air flow through the Andersen Sampler: eight species of *Aspergillus*, four species of *Penicillium*, two species each of *Alternaria* and *Cladosporium* and one species

Table 2 Mean concentration, percentage and statistical significance of the pollen types in the indoor and outdoor environments of the coir factory from 1997 to1999

Taxa	Indoor		Outdoor		Level of significance
	Number of pollen m^{-3}	Percentage	Number of pollen m^{-3}	Percentage	
Acalypha sp.	–	–	1.25	3.08	–
Ageratum conyzoides	–	–	0.42	1.03	–
Amaranthus/Chenopodium	1.04	3.64	0.21	0.52	–
Aporosa lindleyana	0.83	2.91	–	–	–
Arecaceae	0.42	1.47	0.21	0.52	–
Artocarpus sp.	1.04	3.64	3.96	9.74	–
Asteraceae	–	–	1.46	3.59	–
Brownea coccinea	–	–	0.21	0.52	–
Cassia sp.	–	–	0.42	1.03	–
Casuarina equisetifolia	0.21	0.74	–	–	–
Cocos nucifera	7.92	27.73	8.96	22.05	–
Datura metel	0.63	2.21	–	–	–
Eucalyptus globulus	2.5	8.75	0.85	2.04	–
Grasses	6.25	21.88	10.42	25.64	**
Hyptis suaveolens	–	–	1.67	4.11	–
Mimosa pudica	1.46	5.11	–	–	–
Peltophorum pterocarpum	0.63	2.21	–	–	–
Ricinus communis	–	–	0.21	0.52	–
Sida cordifolia	0.42	1.47	2.29	5.63	–
Tridax procumbens	0.21	0.74	2.08	5.12	–
Vernonia cinerea	1.25	4.38	2.29	5.63	–
Vigna trilobata	3.75	13.13	2.29	5.63	–
Unidentified	–	–	1.46	3.59	–
Total pollen	28.56	–	40.64	–	–

** Significant at α value < 0.05

each of *Rhizopus, Curvularia, Fusarium* and *Pestalotiopsis*. *Penicillium citrinum* was the most dominant and frequently isolated species (39% of total CFU) followed by *Aspergillus flavus* (14.28%) and *A. niger* (13.91%) (Table 4).

The highest mean colony concentration of *Penicillium citrinum* occurred in December (120.14 CFU m^{-3} air) and the lowest in February (7.95 CFU m^{-3} air) (Fig. 3), while the peak concentration of *Aspergillus flavus* occurred in February (29.16 CFU m^{-3} air) and its lowest concentration was recorded in July (5.3 CFU m^{-3}) (Fig. 3). *Aspergillus niger* and *A. japonicus* were frequently recorded. The concentration of *A. niger* colonies was very high in November (51.24 CFU m^{-3} air), but no colonies were recorded in September and October (Fig. 3). The highest concentration of *A. japonicus* colonies was recorded in December, but no colonies were recorded in February, July and August. There were slightly more *A. flavus* colonies in 1997–1998 than in 1998–1999, although the reverse was the case with *A. niger*. The highest concentration of *Rhizopus stolonifer* colonies occurred in October (8.83 CFU m^{-3} air) and January (7.95 CFU m^{-3} air). The levels *R. stolonifer* colonies remained constant from March to June (Fig. 3), although its lowest concentration was recorded in February. All other species were recorded in the air only intermittently.

3.3 Pollen concentration

In the indoor environment, the highest total pollen count was recorded in October and April

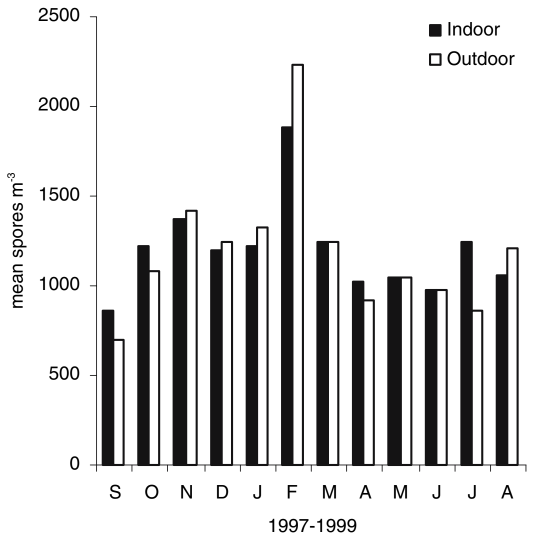


Fig. 1 Annual spore distribution in the coir factory environment

(42.5 pollen m^{-3} air, respectively),whereas in the outdoor environment, there were two peak concentrations – in November (67.5 pollen m^{-3} air) and July (120 pollen m^{-3} air). The lowest pollen incidence was recorded in September in the indoor environment (12.5 pollen m^{-3} air) and in May and August in the outdoor environment (Fig. 4). *Cocos nucifera* pollen contributed to 27.73% of the total pollen recorded inside the factory, followed by grass pollen (21.88%); the reverse was true in the outdoor environment where grass pollen accounted for 25.64% of the toal pollen and *Cocos nucifera* pollen for 22.05% (Table 2).

Cocos pollen was captured in higher concentrations from January to March in the indoor environment and from January to April in the outdoor environment. It was absent in November, June and July in the indoor environment, but was present throughout the study period in the outdoor environment (Fig. 5). The indoor concentration of *Cocos* pollen in 1997–1998 (11.25 pollen m^{-3} air) was significantly higher than that in 1998–1999 (4.58 pollen m^{-3} air) ($\alpha < 0.05$) (Table 3).

The mean concentration of grass pollen was significantly higher ($\alpha < 0.05$) outdoors (10.42 pollen m^{-3} air) than indoors (6.25 pollen m^{-3} air)(Table 3). In the indoor environment, the maximum incidence of grass pollen occurred in July (17.5 pollen m^{-3} air),

Fig. 2 Monthly variations in dominant fungal spore types

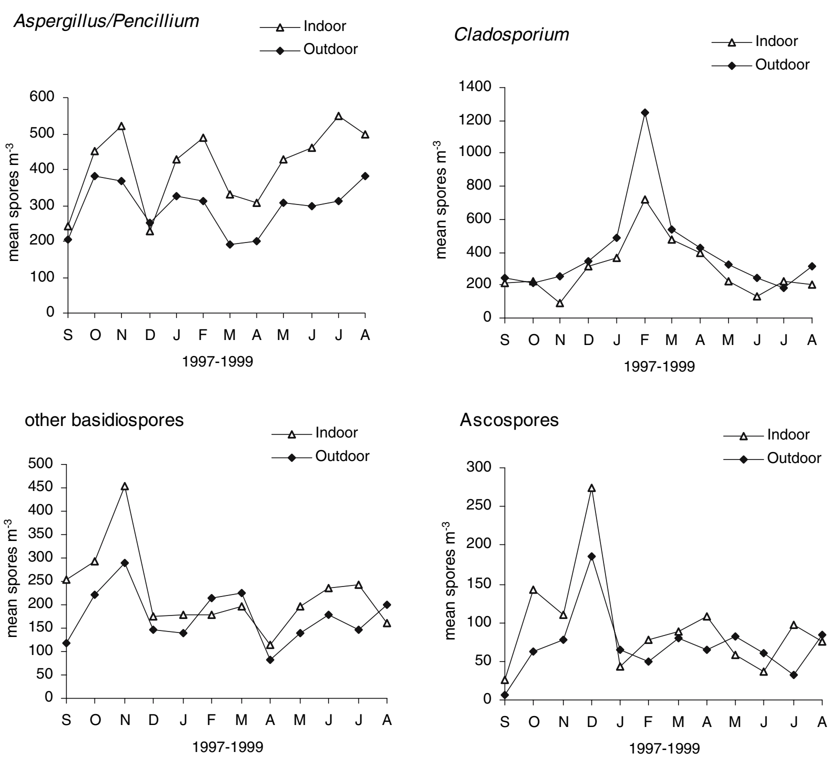


Table 3 Mean concentration and level of significance of dominant spores and pollen in the indoor and outdoor environments during 1997–1998 and 1998–1999, respectively

Taxa	Indoor		Significance level	Outdoor		Significance level
	1997–1998	1998–1999		1997–1998	1998–1999	
Aspergillus/Penicillium	398.75	423.75	–	237.50	350.42	*
Cladosporium	294.17	303.75	–	430.00	376.25	–
Other basidiospores	184.17	262.08	*	93.75	255.00	*
Ganoderma	31.67	39.58	–	30.00	86.67	*
Ascospores	28.33	160.83	*	33.75	103.33	**
Nigrospora	31.25	61.25	**	26.67	56.67	**
Cocos nucifera	11.25	4.58	**	10.83	7.08	–
Grass	6.25	6.00	–	12.08	8.75	–
Artocarpus	2.08	1.25	–	4.16	3.75	–
Eucalyptus	2.5	2.0	–	1.23	1.66	–
Total spores	1040.41	1352.5	*	1043.33	1235.42	–
Total pollen	32.50	24.58	–	53.75	27.5	*

* Significant at $\alpha < 0.01$; ** Significant at $\alpha < 0.05$

Table 4 Mean concentration and percentage of culturable fungi inside the coir factory from 1997 to1999

Taxa	CFU m^{-3}	Percentage
Alternaria alternata	0.59	0.59
Alternaria sp.	1.69	1.69
Aspergillus flavipes	0.3	0.29
Aspergillus flavus	14.28	14.28
Aspergillus fumigatus	2.21	2.21
Aspergillus glaucus	0.22	0.22
Aspergillus japonicus	4.56	4.5
Aspergillus niger	13.96	13.91
Aspergillus restrictus	1.47	1.47
Aspergillus wentii	0.59	0.59
Cladosporium cladosporioides	0.37	0.36
Cladosporium sp.	1.03	1.03
Curvularia sp.	0.22	0.21
Fusarium oxysporum	0.23	0.22
Penicillium citrinum	39.02	39
Penicillium chrysogenum	11.85	11.84
Penicillium digitatum	0.22	0.22
Penicillium frequentans	1.4	1.2
Pestalotiopsis	0.07	0.07
Rhizopus stolonifer	5.35	5.37
Unidentified	0.44	0.44

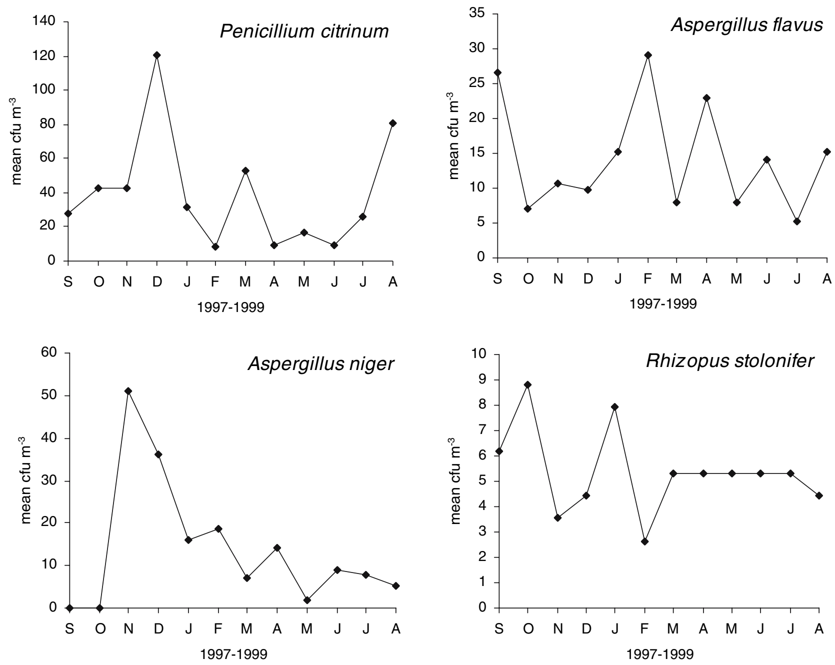
but grass pollen was not recorded in February and April. In the outdoor environment, the incidence of grass pollen resembled that of *Cocos* pollen: it was captured during all the months of the study, with the highest incidence in November (22.5 pollen m^{-3} air) and the lowest incidence in October (2.5 pollen m^{-3} air) (Fig. 5).

Other pollen types (*Artocarpus, Eucalyptus, Terminalia, Aporosa* etc.) were captured mostly in specific periods as these species possessed specific phenological periods. *Eucalyptus* pollen was recorded from December to May indoors and in December and February and up to March outdoors; *Artocarpus* pollen was recorded from December to April outdoors and in February and April indoors (Fig. 5). Pollen of *Vigna trilobata*, a herbaceous weed, contributed 13.13% to the total pollen count indoors and 5.63% outdoors, but it was recorded only in July and October indoors and in July and August outdoors. All other pollen types (Table 2) occurred only sporadically in the coir factory environment.

4 Discussion

Many authors have surveyed airborne fungal spores in working environments (Chakraborty et al. 2000; Kakde et al. 2001; Lugauskas et al. 2000; Santra and Chanda 1989; Simsekli et al. 1999) although only a very few studied airborne pollen in similar environments (Maribhat and Rajasab 1988; Tilak 1987–1988). The present study is the first to analyse the

Fig. 3 Monthly distribution of dominant colony-forming fungi



incidence and concentrations of pollen and spores in the indoor and outdoor environments of a coir factory. Our results showed that the air in the coir factory was contaminated with fungal propagules, pollen and coir pith.

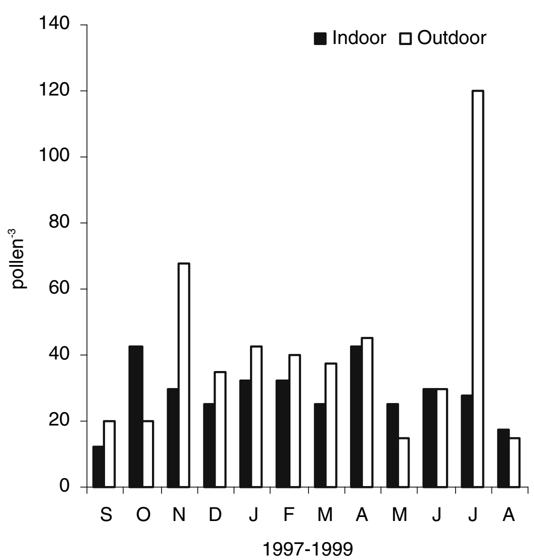
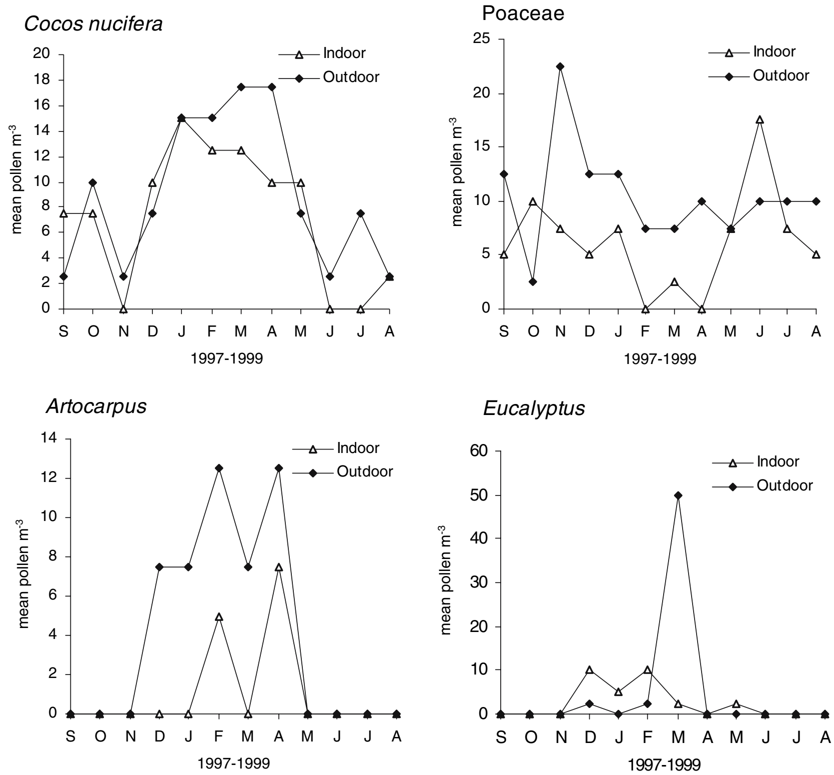


Fig. 4 Annual pollen distribution in the coir factory environment

The pollen to fungal spore ratio was approximately 1:28 in the coir factory environment (see Tables 1 and 2). This is in agreement with results from previous studies in which the annual mean concentration of pollen was found to be much lower than that of fungal spores in many working environments. Maribhat and Rajasab (1988) observed a pollen to spore ratio of 1:10 in a commercial location in Gulberga in Maharashtra. Tilak and Patil (1981) used a Rotorod Sampler to analyse the airspora of a dwelling house and found that pollen constituted only 5.4% of the total airspora compared to 70.55% for fungal spores. Singh (1981) recorded very high concentrations of fungal spores relative to pollen grains in a cinema hall in Manipur, although he did not provide a definite pollen to fungal spore ratio. All of these authors explained this remarkable variation in observed pollen and spore concentrations as possibly originating in the easy availability of abundant growth substrates for fungi and the phenological specificity of flowering plants in the surveyed areas. We also suggest that these are the main factors for our pollen to spore ratio of 1:28 in the coir factory environment. Coir wastes would provide enough growth substrate for fungal propagules, resulting in the release of a high proportion of fungal spores. Our phenological study indicated that all plant species,

Fig. 5 Monthly variation in dominant pollen types



with the exception of *Cocos nucifera*, had specific flowering periods. This seasonality caused a decrease in the total annual pollen concentration. Davies (1969) remarked that an indoor environment that is open to natural ventilation to the ambient atmosphere could attract seasonally occurring pollen and spores from the outside environment but at a much lower concentration. The present study showed that total pollen and spore concentrations were more or less similar in the indoor and outdoor environments of the coir factory. Two possible explanations for this result are: (1) a continuous strong wind from the sea coast, which is only 4 km from the factory, and (2) well-ventilated factory walls. Both of these factors are not incidental and may have a lasting effect on the total pollen and spore concentrations throughout the year.

4.1 Fungal spores

Our records on the monthly spore incidence showed that the highest concentration of fungal spores occurred in February in both the indoor and outdoor environments and that fungal spores were present at fairly high concentrations in all of the other months except for September. *Aspergillus/Penicillium*, *Cladosporium*, ‘other basidiospores’ and ascospores together constituted 85.92% of the total fungal spores found indoors and 79.03% of those found outdoors.

Studies conducted in India and elsewhere in working environments such as bakeries (Singh and Singh 1994), markets and jute mills (Chakraborty et al. 2000), fibre board factories (Dutkiewicz et al. 2001), warehouses (Simsekly et al. 1999; Lugauskas et al. 2000), poultry sheds (Crook 1994; Singh and Singh 1999; Jothish and Nayar 2003) and flour mills (Misra and Jamil 1991) have reported a dominance of *Aspergillus/Penicillium* in indoor environments. In a review on airborne fungal spores, Burge (1989) mentions that fungal genera are normally not abundant in outdoor environments, but those associated with indoor contamination include *Aspergillus* and *Penicillium*. It is possible that the main factor determining the prevalence of *Aspergillus* and *Penicillium* is the presence of growth media in indoor environments, especially in agriculture-based industries. Such fungal species can grow temporarily even on wet surfaces and sporulate (Pasanen et al. 1991). Fibre waste and coir stored in a humid atmosphere both inside and outside the coir factory would provide suitable media for *Aspergillus* and *Penicillium*. In support of this, the peak concentrations of these two fungal species occurred during the rainy season (June–November) as these conditions favour fungal growth.

Aspergillus and *Penicillium* constituted about 90% of the total CFU in the culture plates. Four species of *Penicillium* were the most dominant spore types, contributing more than 50% of the total CFU, and eight species of *Aspergillus* accounted for 37.53% of the total CFU (see Table 4). A study conducted by Jayaprakash et al. (1978) in a granary in Mysore showed that *A. flavus* was the most dominant component of the spores present. In a similar study conducted in a leather godown, Pugalmaran and Vittal (1997) reported the dominance of *A. niger* followed by *P. citrinum*. Singh and Singh (1999) considered *A. flavus* and *A. niger* to be the most dominant components in the indoor environment of work places such as bakeries, poultry farms and hospital wards. In a fruit market environment, Kakde et al. (2001) found a high concentration of *A. flavus, A. niger* and *P. citrinum*. In indoor environments of secondary schools and kindergartens in Lithuania, Lugauskas et al. (2000) observed that *Penicillium* formed the largest fraction among the spore types present. Rural areas in Spain with high populations of pig barns harboured *A. flavus, A. niger* and *P. citrinum* as the most dominant components of the airspora (Amigot Lazaro et al. 2000). High concentration of *A. fumigatus, A. niger* and *P. citrinum* have been recorded in fibre board and chip board factories in Poland (Dutkiewicz et al. 2001), while pig-rearing barns and poultry confinement buildings in the UK were found to be highly contaminated with *Aspergillus* and *Penicillium* species (Crook 1994).

Dominant culturable fungi such as *A. flavus* did not exhibit a clearly defined seasonal periodicity in our study, but *P. citrinum* showed peak concentrations during the rainy and winter seasons. However, there have been instances where culturable fungi have shown seasonal periodicities in indoor environments such as libraries, bake houses, hospital wards and markets in India (Santra and Chanda 1989; Singh et al. 1995). Ebner et al. (1989) showed that *Aspergillus* did not exhibit seasonal periodicity as does *Penicillium* in outdoor environments. The papers mentioned above suggest that differences in weather conditions and the availability of growth substances influence the concentration of fungal spores in both indoor and outdoor environments alike.

Cladosporium was the second dominant fungal spore type inside the coir factory although it ranked as the most dominant spore type in the outdoor environment. Jothish and Nayar (2003) reported a similar condition in a poultry farm in Kerala, where the concentration of *Cladosporium* was higher outdoors than indoors. In a fruit market in Nagpur, Kakde et al. (2001) reported *Cladosporium* to be one of the most dominant spore types, with *C. herbarum* as the most dominant form. In hospital wards, chira mills, market and storage places in West Bengal, Chakraborty et al. (2000) found that *Cladosporium* was the second dominant spore type. Studies conducted in food production facilities and warehouses in Turkey (Simsekly et al. 1999) and paper mills in Lithuania (Amigot Lazzarro et al. 2000) have reported that *Cladosporium* is the most dominant and frequently isolated genus.

In the present study, the highest concentration of *Cladosporium* spores was observed in both environments from January to April, during the dry and hot months (Fig. 2), which is in agreement with the observations of Jothish and Nayar (2003) in a poultry farm and Misra and Jamil (1991) in a flour mill. *Cladosporium* can grow on various organic materials because of its saprotrophic and parasitic nature. It grows well during the rainy season and start sporulating towards the end of the season. Being a component of 'dry spores', its conidia are released in large numbers during dry and hot months.

In our survey 'other basidiospores' and *Ganoderma* showed higher concentration during the rainy season (July–November), as has generally been observed in tropical countries (see Lacey 1990). The captured ascospores consisted of seven spore types. Being a part of 'wet spores' they showed high concentrations from October to December. The humid atmosphere during these months naturally favoured the release of ascospores in large numbers. *Rhizopus stolonifer*, a zygomycetes fungus reported in hospital wards, residential quarters, markets, food storage places, flour mills and shoe markets (see Santra and Chanda 1989; Lugauskas et al. 2000) was trapped abundantly in the culture plates exposed in the coir factory.

The outdoor environment appears to be the major source of *Cladosporium*, 'other basidiospores', *Ganoderma* and *Nigrospora* because: (1) *Cladosporium* and *Ganoderma* were found abundant in the outdoor environment, (2) culture growth of *Nigrospora* was not found in plates exposed inside the factory during the entire period of the study and (3) the coir pith which acts as fungal growth substrate was abundant in the outdoor environment. Organic wastes deposited in and around the factory and surrounding vegetation may be source of the other spore types, mostly hyphomycetes, recorded in the coir factory. Although this study is the first to report on the presence of fungal spores in the coir factory environment, the difference between the spore incidence here and that observed in other working environments, such as poultry sheds, bakeries and markets, is not large, and the dominant spore types were almost similar in the coir factory and other working environments surveyed in India.

4.2 Pollen grains

Airborne pollen flora captured in the coir factory reflected the local vegetation. A lower concentration of pollen was recorded in the indoor environment, probably because pollen could only enter into the factory air through the ventilation system. In support of this, Tilak and Pillai (1988) reported a distinctly lower concentration of pollen inside a much less ventilated library than in the outdoor environment in Aurangabad.

We found marked differences in tree and shrub pollen in the indoor (49.64%) and outdoor (36.34%) environments over a period of 2 years. This difference is due to the abundance of *Cocos* and *Eucalyptus* pollen, as both types of plants are planted inside the factory compound. The rate of airflow from outside the factory to inside the factory is remarkably high due to the persistent sea wind. Consequently, the rate of pollen entering the factory from the outdoor environment is always relatively high. Once into the air of the factory, it accumulates there as there is no powerful air source to blow the pollen back outdoors, resulting in a high concentration of pollen inside the factory. The concentration of herbaceous pollen was reported to be higher than that of trees and shrubs inside a hospital ward in Aurangabad and in a commercial complex in Gulberga (Tilak 1987–1988; Maribhat and Rajasab 1988). We suggest that the occurrence of pollen in each case should be considered in the light of the surrounding environment as the composition of vegetation in the study site and the structural pattern of the building play an important role – in addition to weather – in the prevalence of pollen.

The incidence of pollen was higher towards the end of rainy season and dry season (October–April). Low relative humidity and high temperatures during dry weather enhances the prevalence of pollen in the atmosphere. Observations made by Maribhat and Rajasab (1988) in Gulberga showed that the high incidence of pollen found from July to November, with a peak in October, should be attributed to the profuse growth of grasses and herbaceous plants during the monsoon.

The most dominant pollen types recorded in both the indoor and outdoor environments of the coir factory were those of *Cocos* and grasses, followed by pollen of *Artocarpus* and *Eucalyptus*. Pollen grains of *Cocos nucifera* were present throughout the year as these plants flower year-round. However, higher concentrations were observed from December to May because of the abundant flowering of this species during this period. The annual concentration of *Cocos* pollen in the indoor environment was found to be more than 5%. The reason for this has been discussed above.

The occurrence of *Eucalyptus* and *Artocarpus* pollen from December to May and from December to April, respectively, synchronized mostly with the flowering periods of these species. *Artocarpus* flowered from October to May and *Eucalyptus* from October to June. *Casuarina* flowered from February to September and *Aporosa* from January to May, but their concentrations in the air, like the shrub pollen represented by *Ricinus communis* and *Datura metel*, was negligible.

Although observed year-round, the concentration of grass pollen peaked from November to January in the post-monsoon period in the outdoor environment as the season coincided with the flowering time of annual grasses. Annuals are more predominant in the surrounding area than perennials. The pollen grains of *Vigna*, *Tridax*, *Vernonia* and *Acalypha* species were recorded at comparatively high concentrations (see Table 2), which is a faithful reflection of the surrounding herbaceous vegetation.

4.3 Conclusions

We report here the first survey of a coir factory for the presence of airborne pollen and fungal spores. Our results show that fungal spores were the most dominant and highly prevalent components in the atmosphere of the coir factory. *Aspergillus*, *Penicillium*, *Cladosporium*, 'other basidiospores', ascospores, *Nigrospora* and *Ganoderma* were the dominant spore types and *Cocos nucifera*, grasses, *Artocarpus* and *Eucalyptus* were the dominant pollen types in the coir factory environment. All dominant spore and pollen types, with the possible exception of *Artocarpus*, are reported to be allergenic and therefore have the potential to elicit allergic/respiratory disorders among workers in the coir factory.

The coir factory working environment is clearly contaminated with fungal spores and pollen grains. This has certainly reduced the quality of air. An effective ventilation system, which currently does not exist in the factory building, may help to flush out the biopollutants from inside the coir factory. Since 60 persons work at a time, a single person occupies about 13.3 m^3 of air inside the factory. It is possible that wearing dust masks will reduce the risk of a worker becoming sensitized to allergenic pollen and spores.

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