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Characteristics, determinants, and spatial variations of ambient fungal levels in the subtropical Taipei metropolis

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Abstract

This study was conducted to investigate the temporal and spatial distributions, compositions, and determinants of ambient aeroallergens in Taipei, Taiwan, a subtropical metropolis. We monitored ambient culturable fungi in Shin-Jhuang City, an urban area, and Shi-Men Township, a rural area, in Taipei metropolis from 2003 to 2004. We collected ambient fungi in the last week of every month during the study period, using duplicate Burkard portable samplers and Malt Extract Agar. The median concentration of total fungi was 1339 colony-forming units m^{-3} of air over the study period. The most prevalent fungi were non-sporulating fungi, *Cladosporium*, *Penicillium*, *Curvularia* and *Aspergillus* at both sites. Airborne fungal concentrations and diversity of fungal species were generally higher in urban than in rural areas. Most fungal taxa had significant seasonal variations, with higher levels in summer. Multivariate analyses showed that the levels of ambient fungi were associated positively with temperature, but negatively with ozone and several other air pollutants. Relative humidity also had a significant non-linear relationship with ambient fungal levels. We concluded that the concentrations and the compositions of ambient fungi are diverse in urban and rural areas in the subtropical region. High ambient fungal levels were related to an urban environment and environmental conditions of high temperature and low ozone levels.

Keywords: Aeroallergens; Aerobiology; Bioaerosols; Culturable fungi; Subtropical

1. Introduction

Aeroallergens, such as fungal spores and pollens, are ubiquitous in our daily environments (Burge and Otten, 1999; Burge and Rogers, 2000). Exposures to aeroallergens have been correlated with development of allergic diseases and exacerbation of allergic respiratory symptoms (Anderson et al., 2001; Cakmak et al., 2002; Dales et al., 2004; Herr et al., 2003; Ross et al., 2002; Zureik et al., 2002). More than 80 kinds of fungi were identified as risk factors for allergic respiratory diseases, especially

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Aspergillus fumigatus, *Cladosporium herbarum*, and *Alternaria alternata* (Burge and Rogers, 2000). These fungi were also considered important factors causing allergic rhinitis and asthma (Achatz et al., 1995; Kurup et al., 2000). Recently, several studies suggested that outdoor airborne fungal concentration is associated with the increase in admission and emergency visit for asthma exacerbations (Anderson et al., 2001; Dales et al., 2004; Lewis et al., 2000; Newson et al., 2000). Exposure to aeroallergens is a special health concern in Taiwan, because the warm and humid climate in this subtropical area provides favorable environmental conditions for microbial and plant growth. One study reported that 21.5% asthmatic children in Taipei, Taiwan had allergic reaction to fungi (Chou et al., 2002).

Studies have shown that ambient fungal variations were associated with meteorological conditions (Ho et al., 2005; Troutt and Levetin, 2001; Wu et al., 2004). Troutt and Levetin (2001) found that dry-air spora (e.g., *Cladosporium*, *Alternaria*, *Epicoccum*, *Drechslera*, *Pithomyces*, *Curvularia* and smut spores) were more abundant in warmer climates, and that high humidity facilitated wet-air spora (e.g., ascospores and basidiospores) to release spores. Although several studies have shown that the concentrations of airborne fungi increase with higher temperatures, studies of relationships with other climatic factors and air pollutants have been inconsistent (Angulo-Romero et al., 1999; Burch and Levetin, 2002; Corden and Millington, 2001; Hollins et al., 2004; Katial et al., 1997; Stennett and Beggs, 2004; Troutt and Levetin, 2001). More studies are needed to clarify their complex interactions.

The distributions and determinants of ambient fungi are not well characterized in Taiwan, because most of the early studies that report ambient fungal populations in Taiwan used passive samplers, which over estimate fungal taxa with larger spores (Chao et al., 1962; Han and Chuang, 1981; Han et al., 1976; Lu et al., 1969; Tseng and Chen, 1979). Accordingly, we cannot fully estimate potential health risks associated with aeroallergens in Taiwan. Therefore, we implemented a longitudinal study to monitor ambient fungi in both urban and rural areas in Taipei, Taiwan, using active samplers. Our main goal was to evaluate the spatial and temporal distributions, compositions, and determinants of ambient fungi in a subtropical metropolis.

2. Materials and methods

2.1. Sampling locations

We collected samples at two monitoring stations of the Taiwan Environmental Protection Administration (Taiwan EPA) in Shin-Jhuang City (SJCity), an urban area, and Shi-Men Township (SMTown), a rural area, in Taipei metropolis, Taiwan. SJCity is an emerging metropolis (121°27′E, 25°02′N), with an area of 19.7 km^2 and approximately 39,000 residents (population density: 19,816 km^{-2}). SJCity is an important business and industrial center in Taipei County. The majority of SJCity are residential (5 km^2) and industrial areas (3 km^2), with 4 km^2 of agricultural and park lands. The monitoring station in SJCity is located in a park and close to two major highways with heavy traffic (Lee et al., 2006). SMTown is in northernmost Taiwan (121°06′E, 25°03′N) with approximately 12,000 inhabitants (population density: 227 km^{-2}). The total area of SMTown is 51 km^2 and the majority is agricultural land (23 km^2) and residential area (1.7 km^2). Agricultural, wasteland, forest and park areas occupy 43 km^2 of SMTown. The major occupations of the local residents are fishery and farming. The sampling location in SMTown is on seashore and facing East China Sea, with minimal local air pollution sources.

2.2. Fungal sample collection and analysis

We collected ambient culturable fungi using duplicate Burkard Portable Air Samplers for Agar Plates (Burkard Manufacturing Co., Rickmansworth, England) and Malt Extract Agar (MEA) from March 2003 to December 2004. The samplers were calibrated before each sampling day at a flow rate of 20 l min^{-1}. Air sampling was conducted on Tuesday and Thursday in the last week of every month during the study period. Duplicate 2-min samples were collected three times a day (in the morning, afternoon and evening) at the rural site (SMTown), and twice a day (in the morning and afternoon) at the urban site (SJCity). All collected samples were shipped back to the laboratory immediately and were incubated at room temperature for 7–10 days. All the fungal colonies were identified to the level possible by low power microscopy (generally, to genus), and counts recorded by colony type. We used a positive-hole correction table to adjust colony

counts and corresponding concentrations (Willeke and Macher, 1999). Concentrations are reported in colony-forming units per cubic meter (CFU m^{-3}). The averages of duplicate samples were used for the subsequent analyses.

2.3. Environmental parameters

Hourly air pollution and meteorological data were provided by Taiwan EPA. Meteorological data included temperature, relative humidity (RH), dew point, rainfall, and wind speed. Air pollutant data included sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), particulates with aerodynamic diameters less than or equal to 10 μm (PM_{10}), nitrogen monoxide (NO), nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), and non-methane hydrocarbons (NMHC). We used the hourly averages of these environmental parameters measured concurrently with fungal sampling for further analysis.

2.4. Statistical analysis

We used SAS statistical package (v. 8.0, SAS Institute Inc., Cary, NC, USA) to perform data analysis. Mann–Whitney *U* test and exact test (if the recovery frequency was <10 for either site) were used to examine the differences of the fungal levels between the two sampling locations. We evaluated the relationships between ambient fungi and environmental parameters using multiple regressions. We developed regression models for total fungi and the most prevalent fungal genera observed. To account for the serial correlations of fungal measurements, we used PROC MIXED procedure in SAS with an exponential correlation covariance model. Fungal concentrations were transformed using base-10 logarithm to approximate normality in regression analysis. For concentrations lower than the limit of detection, we used 0.1 CFU m^{-3} to avoid zero values.

3. Results

3.1. Compositions and concentrations of ambient fungi

A total of 48 fungal taxa were recovered during 2003–2004 from both sampling locations. Table 1 summarizes the distributions of ambient fungi with more than 5% recovery frequency during the study period. The most prevalent fungal taxa observed were non-sporulating fungi, *Cladosporium*, *Penicillium*, *Curvularia* and *Aspergillus*, present in more than 50% of the samples. Non-sporulating fungi, *Cladosporium* and *Penicillium* were the most dominant fungal taxa in both 2003 and 2004.

During the study period, 45 fungal taxa were found at the urban site and 37 taxa were recovered at the rural site. At the urban site, the most prevalent fungi were non-sporulating fungi (recovery frequency = 100%), *Cladosporium* (96.2%), *Curvularia* (65.4%), *Penicillium* (64.7%), *Aspergillus* (62.4%), and *Alternaria* (42.9%). The taxa observed most frequently at the rural site were *Cladosporium* (97.5%), non-sporulating fungi (95.6%), *Penicillium* (73.0%), *Fusarium* (45.9%), *Aspergillus* (41.5%), and *Curvularia* (41.5%). Total fungi and 9 fungal taxa, including *Cladosporium*, *Curvularia*, *Aspergillus*, *Alternaria*, *Botrytis*, *Coelomycetes*, *Leptosphaerulina*, *Pithomyces*, and *Bipolaris*, had significantly higher concentrations at the urban site than at the rural site ($p<0.05$) (Table 2). The levels of *Penicillium*, *Fusarium* and *Sporotrichum*, on the contrary, were significantly higher at the rural site. Several fungal taxa were only observed at the urban site, including *Rhizopus*, *Zygomycetes*, *Mucor*, *Drechslera*, *Botryosporium*, *Periconia*, *Stachybotrys*, *Torula* and *Wallemia*. *Gliomastix* and *Gliocladium* were only recovered at the rural site.

3.2. Seasonal variations of ambient fungi

Fig. 1 shows the temporal variations of total fungi at both sampling sites in 2003 and 2004. Total fungal levels were generally higher in warmer months. During 2003, the highest total fungal levels were observed in June (median = 2900 CFU m^{-3}) at the urban site and in July (13,760 CFU m^{-3}) at the rural site. In 2004, total fungal concentrations at both sampling locations peaked in June (4145 CFU m^{-3} at the urban site and 3191 CFU m^{-3} at the rural site). Fig. 2 shows the distributions of non-sporulating fungi, the most prevalent fungal category, over the study period. In 2003, the concentrations of non-sporulating fungi were highest in June at the urban site (1111 CFU m^{-3}) and in April at the rural site (1203 CFU m^{-3}). In 2004, non-sporulating fungi had highest levels in September (1101 CFU m^{-3}) and July (668 CFU m^{-3}) at the urban and rural sites, respectively. Most of the

Table 1
Descriptive statistics for ambient fungal concentrations (CFU m^{-3}) in Taipei metropolis during 2003 and 2004

Fungal categories[a]	Freq. (%)[b]	Mean	Median	Std. dev.	Min	Max
Non-sporulating	97.6	507.48	372	449.35	0	2592
Cladosporium	96.9	379.84	274	350.90	0	2563
Penicillium	69.2	77.43	30	127.09	0	1160
Curvularia	52.4	46.61	20	78.28	0	668
Aspergillus	51.0	53.65	12	186.17	0	2558
Fusarium	38.7	17.51	0	32.63	0	274
Alternaria	36.6	22.90	0	44.01	0	307
Yeast	19.5	9.37	0	23.82	0	170
Arthrinium	18.8	7.54	0	24.68	0	306
Botrytis	14.0	4.95	0	14.33	0	100
Coelomycetes	14.0	7.00	0	27.54	0	327
Trichoderma	12.0	2.92	0	8.55	0	47
Geotrichum	9.6	9.61	0	58.95	0	713
Leptosphaerulina	9.3	3.05	0	11.39	0	105
Aureobasidium	8.9	3.41	0	13.07	0	93
Nigrospora	8.2	2.51	0	9.83	0	68
Candida	7.9	2.63	0	10.05	0	77
Sporothrix	7.9	3.49	0	18.22	0	253
Verticillium	5.5	1.69	0	8.41	0	96
Total fungi	100	2257.39	1339	3221.60	0	25,935

[a]Other observed fungi (recovery frequency < 5%) not included in this table are *Pithomyces*, *Trichophyton*, *Neurospora*, *Paecilomyces*, *Bipolaris*, *Chaetomium*, *Sporotrichum*, *Acremonium*, *Rhizomucor*, *Rhizopus*, *Rhinocladiella*, *Ulocladium*, *Zygomycetes*, *Mucor*, *Pestalotiopsis*, *Drechslera*, *Epicoccum*, *Exserohilum*, *Microsporum*, *Scopulariopsis*, *Xylohypha*, *Botryosporium*, *Gliomastix*, *Gliocladium*, *Periconia*, *Stachybotrys*, *Torula* and *Wallemia*.

[b]Frequency was the percentage of samples (total $n = 292$) with presence of that specific fungal category.

Table 2
Distributions of selected ambient fungi in urban and rural areas during 2003 and 2004

Fungal categories (CFU m^{-3})[a]	Urban ($n = 133$)				Rural ($n = 159$)				p-Value[b]
	Freq. (%)[c]	Mean	Median	Std. dev.	Freq. (%)	Mean	Median	Std. dev.	
Total fungi	100.0	2233.16	1643	2676.10	100.0	2277.66	1085	3623.70	0.0122
Cladosporium	96.2	445.70	363	382.43	97.5	324.74	230	312.86	0.0015
Penicillium	64.7	53.89	23	75.89	73.0	97.11	43	155.18	0.0180
Curvularia	65.4	63.56	37	94.31	41.5	32.44	0	58.41	<0.0001
Aspergillus	62.4	85.62	23	263.98	41.5	26.91	0	63.53	<0.0001
Fusarium	30.1	14.25	0	37.18	45.9	20.24	0	28.11	0.0013
Alternaria	42.9	25.15	0	38.11	31. 5	21.01	0	48.44	0.0411
Botrytis	24.1	8.88	0	18.86	5.7	1.66	0	7.55	<0.0001
Coelomycetes	18.8	9.32	0	33.09	10.1	5.06	0	21.76	0.0338
Leptosphaerulina	13.5	4.02	0	11.23	5.7	2.24	0	11.50	0.0214
Pithomyces	7.5	4.06	0	22.07	2.5	0.75	0	4.93	0.0446
Bipolaris	6.0	3.05	0	15.63	0.6	0.38	0	4.80	0.0100
Sporotrichum	0.8	0.59	0	6.85	5.0	2.69	0	13.46	0.0395

[a]The fungal taxa included in the table had significantly different concentrations between the two sampling sites.

[b]Mann–Whitney U test or Exact Test was used to examine the differences of fungal levels between the two sampling locations.

[c]Frequency was the percentage of samples with presence of that specific fungal category.

predominant fungi had similar seasonal patterns as the total and non-sporulating fungi, with higher levels in warmer months. However, the concentrations of *Cladosporium* peaked both in summer (June–August) and winter (December–January) during the study period (data not shown).

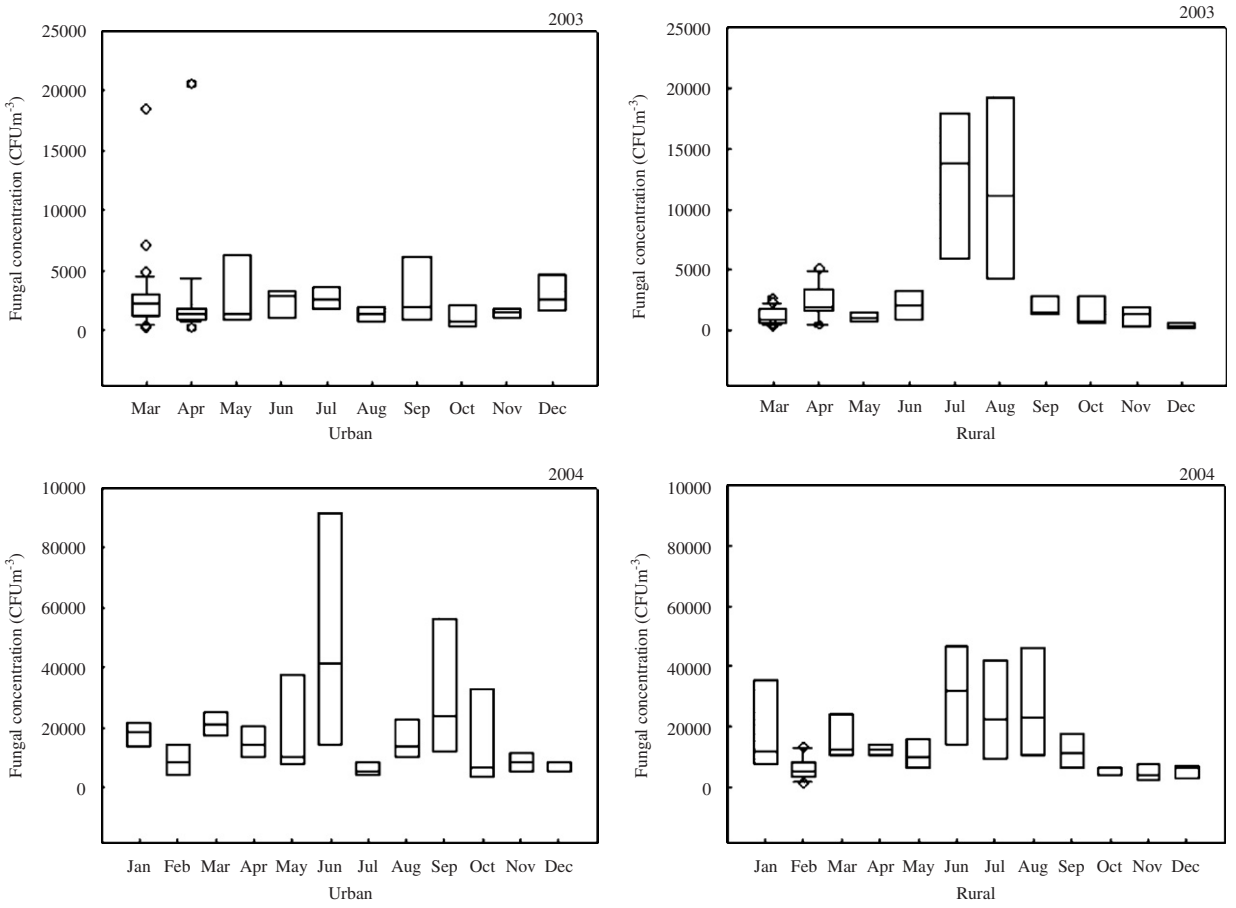

Fig. 1. Seasonal variations of total fungi during 2003 and 2004. The box plots show medians 10th, 25th, 75th, and 90th percentiles and outliers (circles).

3.3. Associations between ambient fungi and environmental parameters

During the study period, most of the air pollutants had higher concentrations at the urban area than the rural area (Table 3). Multiple regression models for major fungal taxa and total fungi are listed in Table 4. In the multiple regression models, temperature was the most consistent predictor of fungal concentrations, which had positive correlations with total fungi, *Penicillium*, *Curvularia*, and *Aspergillus*. Total fungi, *Cladosporium, Penicillium* and *Aspergillus* were correlated with RH nonlinearly ($RH + RH^2$). Wind speed was significantly associated with both non-sporulating fungi and *Curvularia*, yet had diverse effects on their concentrations. Among air pollutants, ozone, CO and CH_4 had significant negative relationships with fungal levels. NMHC, however, was significantly and positively related to non-sporulating fungi. We also found sampling year had significant effects on the levels of total fungi, non-sporulating fungi and *Cladosporium*.

4. Discussion

In this study, we found that total airborne fungal concentrations and diversity of fungal species (as measured by the number of fungal taxa identified) were generally higher in urban than in rural areas. Other gases and particulate pollutants also had higher concentrations at the urban site than the rural site, except CH_4 (Table 3). Local turbulence in high traffic locales, such as SJCity, increases fungal spore aerosolization from surrounding environments and increases ambient fungal levels (Lugauskas et al., 2003). SMTown is a rural seaside town with less urban pollution, as indicated by lower air

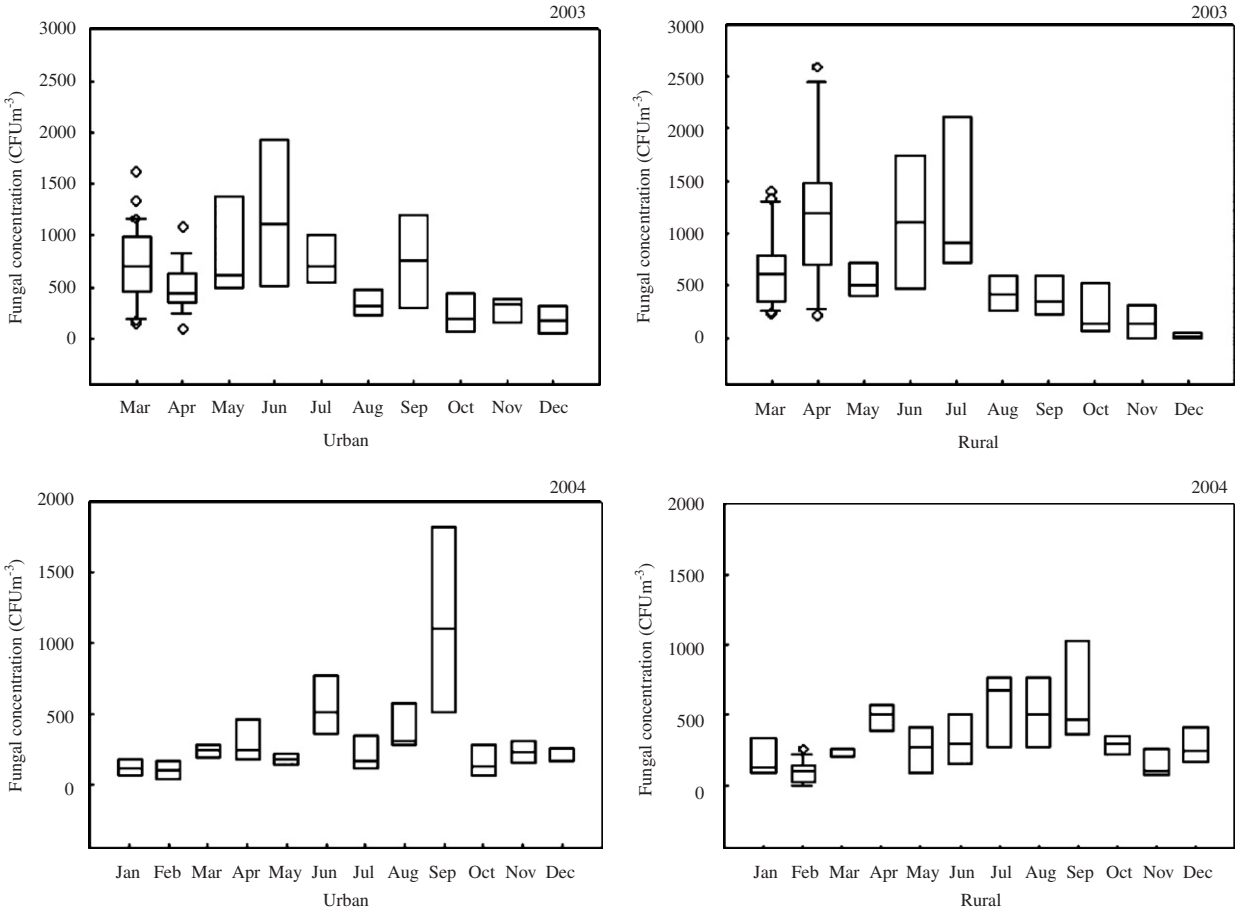

Fig. 2. Seasonal variations of non-sporulating fungi during 2003 and 2004. The box plots show medians 10th, 25th, 75th, and 90th percentiles and outliers (circles).

Table 3
Distributions of environmental factors in urban and rural areas during 2003 and 2004[a]

Environmental factors	Urban				Rural			
	Mean	Std. dev.	Min	Max	Mean	Std. dev.	Min	Max
SO_2 (ppb)	6.9	9.2	0.0	71.2	2.7	3.01	0.0	14.0
CO (ppb)	639.1	333.5	0.0	2100.0	346.4	218.7	0.0	1030.0
O_3 (ppb)	46.7	23.4	0.0	109.0	42.3	20.9	0.0	129.7
PM_{10} ($\mu g\,m^{-3}$)	59.5	32.1	0.0	194.0	45.9	24.9	5.0	143.0
NO (ppb)	3.1	4.6	0.0	44.0	2.2	3.0	−0.2	14.7
NO_2 (ppb)	24.0	12.5	0.0	64.0	9.5	7.5	0.0	46.1
THC (ppb)	2846.3	674.5	0.0	6632.0	2447.8	553.5	123.0	3595.0
NMHC (ppb)	814.9	469.2	0.0	3300.0	180.4	118.7	0.00	664.7
CH_4 (ppb)	2036.2	353.0	0.0	3430.0	2267.3	517.1	50.0	3230.0
Wind speed ($m\,s^{-1}$)	2.6	1.5	0.3	6.6	3.5	2.7	0.2	13.0
Temperature (°C)	26.5	5.4	14.7	36.3	23.8	5.7	8.0	34.2
Dew point (°C)	17.9	3.8	11.0	27.7	19.9	4.1	11.9	28.3
RH (%)	61.0	11.0	38.0	87.1	75.5	10.5	52.7	94.9
Rainfall (mm)	0.06	0.43	0.00	4.40	0.14	0.88	0.00	7.40

[a]Presented data were measured concurrently with the fungal sampling.

Table 4
Multiple regression models for major fungal taxa

	β coefficient	SE	p-Value
Total fungi			
Intercept	24.3484	4.3915	0.1136
Sampling year	−0.2445	0.0490	<0.0001
Temperature	0.0159	0.0035	<0.0001
RH	0.0366	0.0169	0.0315
RH^2	−0.0003	0.0001	0.0289
O_3	−0.0048	0.0011	<0.0001
Non-sporulating fungi			
Intercept	34.5579	7.4414	0.135
Sampling year	−0.3419	0.0804	<0.0001
Wind speed	−0.1041	0.0174	<0.0001
CO	−0.8520	0.1624	<0.0001
NMHC	0.4615	0.1150	<0.0001
Cladosporium			
Intercept	21.9816	8.1832	0.2269
Sampling year	−0.2392	0.0915	0.0094
RH	0.0735	0.0324	0.0238
RH^2	−0.0005	0.0002	0.0240
Penicillium			
Intercept	−4.2463	2.0714	0.2889
Temperature	0.0264	0.0125	0.0350
O_3	−0.0137	0.0041	0.0011
RH	0.1447	0.0584	0.0139
RH^2	−0.0010	0.0004	0.0197
Curvularia			
Intercept	0.1206	0.6042	0.8745
Temperature	0.0427	0.0130	0.0011
Wind Speed	0.0884	0.0404	0.0296
CH_4	−0.4697	0.1922	0.0152
Aspergillus			
Intercept	−5.2477	2.2438	0.2572
Temperature	0.0453	0.0129	0.0005
RH	0.1605	0.0632	0.0118
RH^2	−0.0012	0.0005	0.0131
CH_4	−0.4372	0.2198	0.0479

pollutant concentrations (Table 3). Year-round strong winds in SMTown may dilute local air pollutants, including ambient fungi, as well. Distributions of local vegetation and types of human activities are diverse in SJCity and SMTown, which also contribute to different concentrations and compositions of fungi in the two areas.

Non-sporulating fungi were the most prevalent taxon found in our study. Non-sporulating fungi are species that do not produce spores under the culture conditions provided, mostly formed of basidiospores and ascospores. Using a Burkard Seven-Day Recording Volumetric Spore Trap, we have found that ascospores and basidiospores are the most prevalent fungal taxa at these same sampling sites (unpublished data). *Cladosporium* was also one of the most prevalent fungi found in our study, which is consistent with other studies conducted in Taiwan and other regions of the world (Al-Subai, 2002; Asan et al., 2002; Chao et al., 1962; Colakoglu, 2003; Ho, 1996; Ho et al., 2005; Troutt and Levetin, 2001). *Penicillium*, *Aspergillus* and *Alternaria* were also frequently recovered in our study. All these fungal taxa are considered universal fungi and are common pathogens associated with respiratory allergic diseases (e.g., allergic rhinitis and asthma) (Achatz et al., 1995; Al-Suwaine et al., 1999; Burge and Rogers, 2000; Kurup et al., 2000; Singh et al., 1987).

Seasonal fluctuation of fungal concentration is dynamic, affected by various variables including climate, meteorological factors, local vegetation, and human activities (Burge and Rogers, 2000). In our study, most fungal taxa showed significant seasonal variations, with higher concentrations in warmer months. Similar findings were observed in previous studies conducted in other areas of Taiwan, in Porto Alegre, Brazil, a subtropical city, and in Melbourne, Australia, a temperate city (Chao et al., 1962; Han et al., 1976; Ho, 1996; Ho et al., 2005, Mezzari et al., 2002; Mitakakis and Guest, 2001). We found that the concentrations of *Cladosporium* peaked in both summer and winter. Previous research suggests that the concentrations of *Cladosporium* peak in both cool and warm seasons in subtropical and tropical areas, because winter is usually warm and humid (the rainy season), which promotes spore production and release (Al-Subai, 2002; Calderon et al., 1997; Sabariego et al., 2000; Al-Suwaine et al., 1999; Bunnag et al., 1982; Fernandez et al., 1998; Hollins et al., 2004; Singh et al., 1987; Vittal and Krishnamoorthi, 1988).

Temperature and humidity are important environmental factors determining fungal survival and growth (Burge and Otten, 1999). Many studies found that outdoor fungal concentrations had a positive correlation with ambient temperatures (Burch and Levetin, 2002; Corden and Millington, 2001; Hollins et al., 2004; Sabariego et al., 2000; Stennett and Beggs, 2004; Troutt and Levetin, 2001). Several studies found that the levels of ascospores, basidiospores and some other fungal spores increased with higher humidity (Burch and Levetin, 2002; Sabariego et al., 2000; Stennett and

Beggs, 2004; Troutt and Levetin, 2001). However, high humidity also indicates a rainy condition, which could remove ambient fungal spores by both rainout and washout effects, especially for dry-air spora (Burge and Rogers, 2000; Weber, 2003). Therefore, the effects of RH on ambient fungi were inconsistent in different studies. According to our regression analyses, temperature had positive significant correlations with total fungi, *Penicillium*, *Curvularia* and *Aspergillus*. We also found that RH was significantly related to total fungi, *Cladosporium*, *Penicillium* and *Aspergillus* nonlinearly, possibly due to diverse effects of humidity on spores.

Sampling year was significantly associated with total fungi, non-sporulating fungi and *Cladosporium*, probably because of climate change or vegetation shift during the study period. Some studies indicated that higher wind speed might cause microorganisms to leave their attached surface and suspend in air (Jones and Harrison, 2004). However, other studies found that higher wind speed decreased fungal concentrations because of atmospheric dilution (Sabariego et al., 2000; Stennett and Beggs, 2004). In this study, we also found inconsistent effects of wind speed on fungal concentrations. Wind speed was positively associated with *Curvularia* but negatively correlated with non-sporulating fungi.

Ozone was significantly and negatively correlated with total fungi and *Penicillium*, similar to other studies (Ho et al., 2005; Lin and Li, 2000). Ozone is an ''open air factor,'' toxic to microorganisms in the air (Cox et al., 1973). We also found non-sporulating fungi were positively related to NMHC and negatively associated with CO. Negative associations were observed between CH_4 and *Curvularia* and *Aspergillus* as well. Because few studies examined the effects of air pollutants on airborne fungi, more research are in need to explore the complex interactions between air pollutants and ambient fungi.

5. Conclusion

We conducted a longitudinal monitoring study to characterize ambient fungi in both urban and rural areas in a subtropical metropolis and to examine the interrelationships between fungi, meteorological factors, and air pollutants. Non-sporulating fungi, *Cladosporium*, *Penicillium*, *Aspergillus* and *Curvularia* were the most prevalent fungal taxa during the study period. Airborne fungal concentrations and diversity of fungal species were generally higher in urban than in rural areas. Ambient temperature was the most consistent environmental factor positively correlated with fungal concentrations. RH and wind speed were also important predictors of fungal levels. Moreover, we found several air pollutants such as ozone, CH_4, NMHC and CO had complex interactions with ambient fungi. Because of the adverse health effects of common fungi, future studies should be conducted to examine the interrelationships between environmental parameters and ambient fungi longitudinally and to investigate the impacts of aeroallergens on public health.

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