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Indoor aeromycota in relation to residential characteristics and allergic symptoms

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Abstract

The indoor aeromycota in several rooms of each of 15 residences in Kitchener-Waterloo, Ontario, Canada was studied from December 1991 to September 1993. There were significant differences in airborne spore concentrations among the types of rooms investigated. Numbers of airborne propagules were highest in the living rooms, followed by family rooms, kitchens, bathrooms and bedrooms. The highest fungal diversity was found in kitchens. Generally, presence of dampness and of carpets led to increased numbers of airborne spores. Forced air heating systems, humidifiers, air filters and air conditioners reduced concentrations of airborne fungi. Patients with respiratory allergies and known sensitivity to moulds reported allergic symptoms significantly less severe than average in residences with air conditioners, air filters, humidifiers and forced air heating systems. In damp residences, their symptoms were significantly more severe than the average.

Key words: Airborne fungi, Residential characteristics, Allergy

Abbreviations: CFU – colony forming unit; RH – relative humidity

Introduction

Air quality in indoor environment is being recognized as an important issue in public health. The relationships of airborne microorganisms with indoor air quality and human health remains poorly understood [1]. Although one might expect optimal hygienic conditions in modern homes, schools and working places, health hazards involving moulds are becoming more frequent [2], and respiratory allergies, including asthma, are becoming more frequent and more severe [3–5].

Condensation and dampness in homes are common causes of complaint [6]. A water problem existing for more than three days was invariably associated with increased airborne fungal spore levels [7]. Demonstrating a direct relation between damp housing and ill health is not straightforward [8] and needs further study [6]. Several published studies have been concerned with the adverse effects of aeromycota indoors as related to residential characteristics such as presence of basement, stove, carpets, humidifier and heating systems [9, 10], but the research has rarely been systematically conducted over an extended period.

The objectives of this study were to determine the differences of indoor aeromycota among bathrooms, bedrooms, family rooms, kitchens and living rooms, to define the effects of residential characteristics on the indoor aeromycota, and to determine relations of indoor aeromycota to residential characteristics and allergic symptoms.

Materials and methods

The study was conducted from December 1991 to September 1993 in Kitchener-Waterloo, Ontario, Canada. Fifteen residences were selected as indoor air-sampling sites. One of the residences was occupied by one person, each of five residences by two persons, each of three residences by three persons, each of five

residences by four persons, and one residence by five persons. In 12 of the 15 residences, each housed a patient known to be allergic to moulds by skin test. These patients were chosen by an allergist. In each residence, except in apartments, air samples were taken monthly, between 1:00 pm and 9:30 pm, from six sites: living room, kitchen, bedroom, bathroom, family room, and outdoor. Three apartments do not have family rooms; therefore, only four rooms were sampled.

Three 10 min samples were taken with a Samplair-MK1 or -MK2 particle sampler (supplier: Allergenco, 403-7834 Broadway, San Antonio, TX, 78209, USA) at each site. Samplers were placed on a table 50–80 cm in height for indoor sampling. For outdoor sampling the sampler was placed on the ground. Results from outdoor samplings had been published [11]. Floor in bedrooms and living rooms were wooden, in bathrooms and kitchens linoleum, and in family rooms concrete. The carpets in these rooms were of wall-to-wall artificial fibre: 100% Nylon or 100% Polypropylene. Three samplers drawing 9.0, 15.0 and 15.5 l of air/min (factory calibration) were used in this study. Samplers were assigned to the rooms randomly at each sampling date to avoid sampler effect. In ten residences, the sampling continued for at least a year; but either because the houses were sold or the patients withdrew from the study, the remainder were sampled for only six to nine months. There were 498 samples taken from bathrooms, bedrooms and kitchens respectively, 315 samples from family rooms. Residents were requested to perform only routine daily activities during the sampling periods. At each sampling site and date, temperature and relative humidity (RH) were recorded.

The slides used in sampling were coated with a thin layer of a mixture of 90% vaseline and 10% high melting point wax (w/w) and subsequently mounted with polyvinyl lactophenol under a coverslip. All fungal spores from the samples were quantified and identified under the 40× and 100× objectives of a Nikon light microscope with phase contrast optics. Data collected and analyzed included: (1) conidia of *Alternaria*, *Aspergillus/Penicillium*, *Cladosporium*, and *Epicoccum*; ascospores of *Leptosphaeria*, basidiospores of *Coprinus* and *Ganoderma*; (2) other ascospores and basidiospores which could not be identified to genus; and (3) other unidentified spores (neither ascospores nor basidiospores), hyphal fragments, total fungal spores and total number of genera. Since the conidia of *Aspergillus* and *Penicillium* cannot generally be distinguished from each other under a light microscope, these two genera were recorded as one pooled taxon.

The patients were asked to complete an initial questionnaire and keep an ongoing daily allergy diary. The questionnaire included questions about personal data and habits, disease history, symptoms, residence characteristics (presence of carpet, dampness, air conditioner, filter, humidifier and forced air heating system), residence history and possible dampness/mould problems. Home dampness is defined as moulds visible to naked eyes, water damage, or water in basement [12]. The allergy diary included 18 symptoms of allergic respiratory diseases defined by the allergist (Nose: plugging or stuffed up, itchy, sneezing and running; Eyes: itchy, watery, swelling and redness; Throat: full feeling, swelling, itchy and post-nasal drip; Ears: itchy; Roof of mouth: itchy; Chest: wheezing, tightness, cough and difficulty breathing). The severity of each symptom was indicated by scores of 0-absent, 1-mild, 2-moderate and 3-severe. The patients were instructed for filling the questionnaire and the allergy diary in a consistent way. To avoid recording false symptoms, whenever a symptom from allergy or cold was difficult for a patient to differentiate, the patient was required to consult the allergist to verify it. A visual inspection for defects and other residential characteristics was conducted on the first visit at each site. Unusual changes in the residences were followed up by additional inspections.

The spore concentrations in the rooms sampled were subject to one-way ANOVA and Tukey-Kramer HSD multiple comparisons using SYSTAT [13]. The effects of residential characteristics on indoor airborne fungal spores were analyzed by t-test.

Results

Comparisons of Airborne Fungal Spores from Sampled Rooms. Occurrences of most groups of airborne fungi were highest in the living rooms (Figs. 1, 2 and 3). The concentrations of *Cladosporium* conidia varied significantly among rooms ($p < 0.00$). The mean concentrations of *Cladosporium* conidia in living rooms were highly significantly greater than those in other rooms (Fig. 1), but there were no significant difference among other rooms. Concentrations of *Alternaria* conidia differed significantly among rooms ($p = 0.03$). The concentrations in living rooms were significantly greater than those in family rooms (Fig. 1). Spore concentrations were not significantly different in bath-

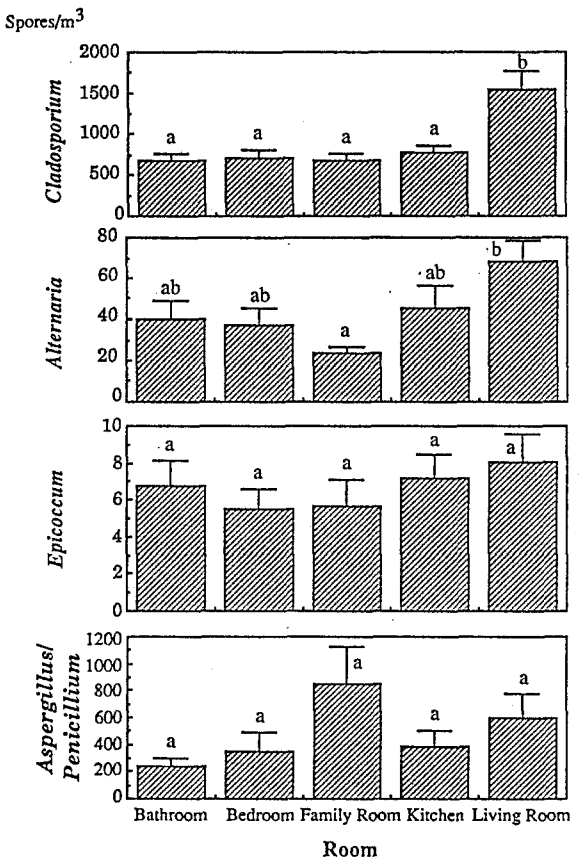

Fig. 1. Yearly mean occurrences of airborne conidia of *Cladosporium*, *Alternaria*, *Epicoccum* and *Aspergillus/Penicillium* in the rooms sampled. Bars with different letters mean significant differences at $p \leq 0.05$.

rooms, bedrooms, family rooms and kitchens (Fig. 1). Concentrations of *Epicoccum* conidia did not differ significantly among the rooms ($p = 0.65$). Although concentrations of *Aspergillus/Penicillium* conidia were quite different, there were no significant differences among rooms ($p = 0.07$).

The counts of *Leptosphaeria* ascospores were not significantly different among rooms ($p = 0.175$) (Fig. 2). Unidentified ascospores in living rooms were found to be significantly more numerous than in bedrooms ($p = 0.02$) (Fig. 2), but there were no significant differences among bathrooms, bedrooms, family rooms and kitchens.

The basidiospore counts of *Coprinus*, *Ganoderma* and unidentified basidiomycetes were significantly different among the rooms ($p < 0.01$, $p = 0.05$, $p < 0.01$). The basidiospore concentrations of *Coprinus* in living rooms were significantly greater than those in bathrooms, bedrooms and kitchens, but not significantly different from those in family rooms (Fig. 2). There were no significant differences among the basidiospore concentrations of *Coprinus* in bathrooms, bedrooms and kitchens. The concentrations of *Ganoderma* basidiospores in living rooms were significantly higher than those in kitchens ($p = 0.03$). There were no significant differences in bathrooms, bedrooms, family rooms and kitchens (Fig. 2). The basidiospores of unidentified basidiomycetes were found at significantly higher concentrations in living rooms than in the other rooms ($p < 0.01, p < 0.01, p = 0.02$ and $p = 0.00$) (Fig. 2). Family rooms had significantly higher spore counts than bedrooms ($p < 0.01$). There were no significant differences among bathrooms, bedrooms and kitchens or among bathrooms, family rooms and kitchens (Fig 2). Although *Leptosphaeria* ascospores were most numerous in family rooms, unidentified ascospores, basidiospores of *Coprinus*, *Ganoderma* and unidentified basidiospores were also numerous in these rooms, and were the most numerous in living rooms (Fig. 2).

Counts of hyphal fragments in the living rooms were significantly greater than those in other rooms ($p < 0.01$, $p < 0.01$, $p = 0.01$ and $p < 0.01$) (Fig. 3). Hyphal fragments in family rooms were significantly more numerous than those in bedrooms ($p = 0.01$). There were no significant differences in hyphal fragments among bathrooms, bedrooms and kitchens, or among bathrooms, family rooms and kitchens (Fig. 3). Unidentified and total airborne fungal spores had significantly different concentrations in the rooms ($p < 0.01$ and $p < 0.01$) (Fig. 3). Unidentified fungal spores were significantly more numerous in living rooms than in the other four rooms ($p < 0.01$, $p < 0.01$, $p = 0.02$ and $p < 0.01$), and those in family rooms were significantly higher than in bedrooms ($p = 0.01$). Total spore counts in living rooms were significantly greater than those in bathrooms, bedrooms and kitchens.

The concentrations of hyphal fragments, unidentified spores and total spores were the greatest in living rooms, second greatest in family rooms, and lowest in bedrooms (Fig. 3).

Airborne fungal diversity was significantly different among rooms ($p < 0.01$) (Fig. 3). The highest diversity was found in kitchens, that in bedrooms and family rooms being significantly lower ($p = 0.01$ and $p = 0.01$) (Fig. 3). The second highest diversity was detected in living rooms, that in family rooms being significantly lower ($p = 0.01$). The lowest level of fungal diversity was in family rooms.

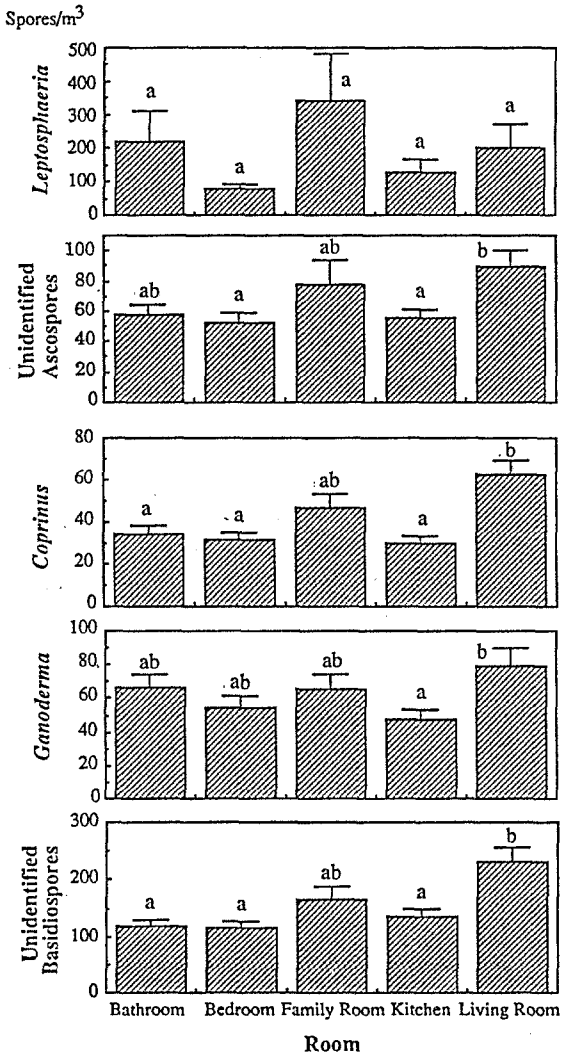

Fig. 2. Yearly mean occurrences of airborne ascospores of *Leptosphaeria*, unindentified ascopores, basidiospores of *Coprinus* and *Ganoderma*, and unidentified basidiospores in the rooms sampled. Bars with different letters mean significant differences at $p \leq 0.05$.

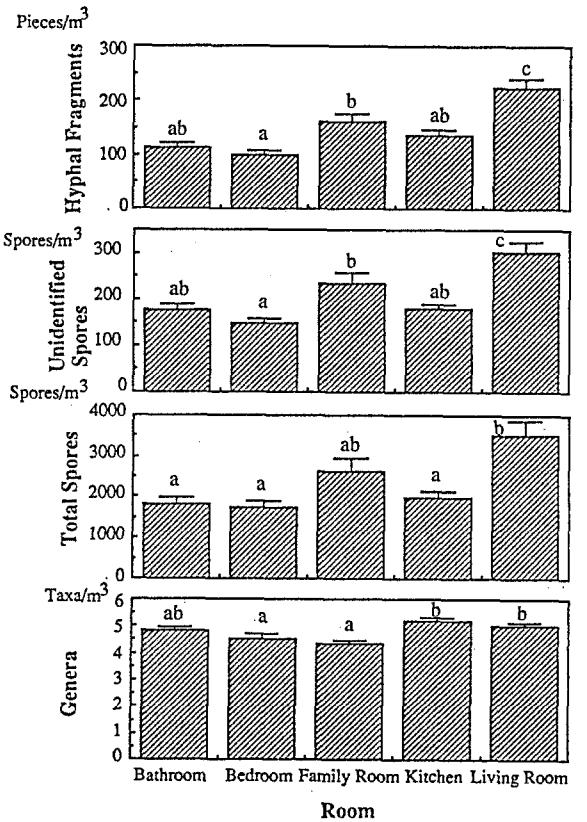

Fig. 3. Yearly mean occurrences of hyphal fragments, unidentified spores, total spores and genera in the rooms sampled. Bars with different letters mean significant differences at $p \leq 0.05$.

House Plants, Relative Humidity and Temperature in the Rooms. Most house plants were found in living rooms. The mean RH in the residences was 41.2 ± 0.4% over one year, with extremes of 33.1% and 55.2%. Average relative humidity in bathrooms (42.4%-highest) was significantly higher than those in kitchens (40.0%-lowest) and there were no significant differences among other rooms (40.6% to 41.9%). The mean annual temperature in the residences was 21.1 ± 0.1 °C, with extreme of 18.8 °C and 23.7 °C. The warmest rooms in the residences were the kitchens (21.9 °C) and in which it was significantly warmer than in the other rooms. The family rooms, usually in the basement, were significantly cooler than the others (19.6 °C).

Effects of Residential Characteristics on Airborne Fungal Spores and the Relations to Symptoms. Air conditioners in use reduced the spore populations of most fungal taxa, either significantly or nonsignificantly (Table 1). According to the t-test, air conditioners had a statistically significant negative effect on spore numbers of most airborne fungal taxa (Table 1), i.e. a significantly lower spore concentration of *Cladosporium*, *Coprinus*, *Ganoderma*, *Leptosphaeria*, unidentified ascospores, unidentified spores, total spores and fungal diversity, but a significantly higher concentration of hyphal fragments. Air conditioners did not appear to have a significant influence on spore populations of the other fungi. Patients in residences with air conditioners in use exhibited significantly less severe symptoms than the average.

Table 1. Influence of characteristics of the residences on the concentrations of indoor airborne fungal spores and the severity of symptoms (unit: spore/m^3, otherwise as indicated)

Taxa	Air conditioner		Carpet		Dampness		Filter		Humidifier		Forced air heating system	
	Absent	Present	Absent	Present	Absent	Present	Absent	Present	Absent	Present	Absent	Present
Cladosporium	1168.5a	698.8b*	588.7a	1091.8b	784.4a	1075.7b	915.4	883.8	935.2	855.7	985.0	829.3
	(127.9)	(53.6)	(51.2)	(96.1)	(88.7)	(75.0)	(76.6)	(86.0)	(111.5)	(56.7)	(83.3)	(88.3)
Alternaria	38.7	48.2	21.8a	57.7b	45.1a	42.9b	35.0	49.3	51.5	37.2	63.8a	30.1b
	(3.0)	(7.1)	(2.0)	(7.0)	(6.7)	(3.3)	(3.0)	(6.5)	(8.4)	(2.6)	(9.8)	(2.2)
Aspergillus/	597.1	356.5	426.7	476.4	309.7a	698.0b	561.1	400.9	385.4	526.4	481.6	439.0
Penicillium	(131.9)	(67.7)	(82.4)	(97.9)	(55.5)	(153.5)	(133.6)	(75.4)	(69.8)	(115.1)	(111.1)	(84.6)
Epicoccum	6.9	6.6	5.3	7.6	5.5a	8.6b	7.8	6.1	7.0	6.4	8.8a	5.1b
	(0.9)	(0.8)	(0.8)	(0.9)	(0.7)	(1.1)	(1.2)	(0.7)	(1.0)	(0.8)	(1.2)	(0.6)
Leptosphaeria	271.9a	117.7b	199.4	170.1	242.6a	83.0b	75.2a	239.6b	284.2a	82.9b	70.6a	263.2b
	(70.3)	(25.5)	(57.1)	(39.7)	(52.4)	(12.8)	(13.3)	(50.0)	(61.3)	(25.5)	(11.2)	(56.2)
Unidentified	33.5a	52.4b	51.3a	74.5b	63.8	68.0	65.0	65.5	68.1	62.7	73.9	59.2
ascospores	(7.2)	(5.0)	(4.8)	(6.1)	(5.4)	(6.7)	(7.1)	(5.2)	(6.4)	(5.5)	(7.9)	(4.4)
Coprinus	49.2a	34.4b	31.4a	46.9b	34.6a	51.0b	44.1	39.1	38.8	42.8	41.3	40.5
	(3.8)	(2.3)	(2.5)	(3.0)	(2.7)	(3.2)	(3.1)	(2.7)	(2.7)	(3.1)	(2.8)	(3.0)
Ganoderma	68.3a	52.3b	44.7a	68.2b	52.1a	70.3b	63.4	56.6	53.6	64.2	58.5	59.3
	(5.9)	(4.6)	(4.4)	(5.3)	(4.4)	(6.4)	(6.6)	(4.4)	(5.3)	(5.1)	(5.7)	(4.8)
Unidentified	184.4a	128.7b	124.2a	169.8b	130.7a	186.6b	190.8a	131.0b	166.2	138.1	168.6	139.8
basidiospores	(12.8)	(9.3)	(8.6)	(11.2)	(7.7)	(15.6)	(16.7)	(7.5)	(12.0)	(9.5)	(14.0)	(8.3)
Unidentified spores	242.1a	181.0b	164.1a	233.8b	188.9a	235.3b	224.9a	196.6b	229.1a	184.5b	217.9	198.2
	(12.0)	(7.1)	(7.0)	(9.7)	(8.0)	(11.1)	(11.1)	(8.0)	(9.7)	(8.7)	(10.1)	(8.6)
Total spores	2920.0a	1868.1b	1826.7a	2616.2b	2050.8a	2726.8b	2408.6	2252.7	2467.8	2151.1	2414.4	2229.1
	(227.2)	(102.3)	(127.2)	(165.3)	(145.5)	(176.1)	(170.3)	(146.8)	(178.0)	(138.8)	(161.4)	(154.9)
Hyphal fragments	142.3a	148.9b	107.5a	171.0b	135.8a	163.1b	159.5a	139.0b	172.7a	120.3b	180.7a	121.0b
(pieces/m^3)	(6.8)	(7.7)	(5.4)	(7.9)	(7.5)	(6.8)	(7.6)	(7.1)	(9.5)	(4.7)	(10.8)	(4.6)
No of genera	5.1a	4.6b	4.8	4.8	4.5a	5.4b	5.2a	4.6b	4.9	4.8	5.1a	4.6b
(taxa/m^3)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Symptom	5.8a	4.7b	5.4	5.0	3.9a	7.2b	6.8a	4.3b	6.0a	4.3b	5.8a	4.7b
(index)	(0.3)	(0.2)	(0.3)	(0.2)	(0.2)	(0.2)	(0.3)	(0.2)	(0.3)	(0.2)	(0.3)	(0.2)

*a and b indicate significant differences; absence of letters indicates non-significant differences; standard error in brackets.

In most cases, significantly greater spore concentrations were found in carpeted rooms (Table 1), i.e. *Alternaria*, *Cladosporium*, unidentified ascospores, *Coprinus*, *Ganoderma*, unidentified basidiospores, unidentified spores, total spores and hyphal fragments. The other fungal taxa were not significantly affected by the presence of carpet. The allergic symptoms did not change significantly in the presence of carpets.

The airborne fungal spore counts of *Aspergillus/Penicillium*, *Cladosporium*, *Coprinus*, *Ganoderma*, unidentified basidiospores, unidentified spores, total spores, hyphal fragments and number of genera were significantly greater in damp residences (Table 1). Fewer spores of *Alternaria* and *Leptosphaeria* were found in the damp residences. There were no significant differences in the occurrence of unidentified ascospores. The symptoms in damp residences were significantly more severe than the average (Table 1).

Residences with filters in the ventilation or heating systems showed a significantly lower concentration of unidentified basidiospores and a lower fungal diversity than those without filters (Table 1). There were significant reductions in most of the fungal taxa. Allergic symptoms were significantly less severe in residences with filters than in those without them (Table 1).

Most fungal taxa did not show significant differences where humidifiers were installed, but significantly lower counts of *Leptosphaeria*, unidentified spores and hyphal fragments were recorded (Table 1). Patients in residences with humidifiers in use suffered significantly less severe symptoms than those who lived in houses without humidifiers (Table 1).

Significantly lower concentrations of *Alternaria*, *Epicoccum*, *Leptosphaeria*, hyphal fragments, and fewer genera over-all, were found with forced air heating systems (Table 1). No significant differencces were recorded for other major fungal taxa. Less severe symptoms were experienced by patients in residences with forced air heating systems in use (Table 1).

Discussion

Lehtonen et al. [14] observed that most everyday activities had an obvious effect on the populations of airborne fungi. According to these authors, short-term human activities in houses explain most of the wide variation in fungal spore concentrations found in indoor air. Settled fungal spores could be resuspended by air movements caused by human activities [14, 15]. Buttner and Stetzenbach [1] found that human activities preceded retrieval of significantly higher concentrations of airborne fungal spores. More activities occurred in the living rooms than in the other rooms was one of the reasons for highest spore counts.

Other reasons for these higher counts were that most of the living rooms were close to the door giving access from outside, and also had the biggest windows in the residences. Since outdoor airborne fungi had, to different degrees, influences on those indoors [11, 14], living rooms had the greatest potential exposure to ingress of outdoor airborne fungi.

The family rooms had the second highest spore counts. This was probably because they were located in the basements where dampness and condensed water problems were most commonly reported. These factors are important promoters of indoor fungal growth.

In our study, spore populations in kitchen were at intermediate levels. The samplings were never conducted during periods of food preparation. Nevertheless, the greatest fungal biodiversity was recorded in kitchens, which seems to be due to the fact that moulds growing on food were released during food preparation. Lehtonen et al. [14] noticed that washing vegetables and other food handling activities could increase spore counts by several times, but after these activities ceased, the spore counts fell dramatically within 30 min. Spores settled on the floor and the surfaces of furniture, but could in many cases be easily resuspended by air movement or human activities.

Very little activity occurred in bedrooms during the daytime, helping to explain why the lowest overall spore counts were found in these rooms. The spore populations recorded in bathrooms were at average levels. High RH in bathrooms was a potential promoter of fungal growth, but no visible fungal colony was noticed in the bathrooms sampled. Cleanliness was probably the major factor keeping the spore levels low in this case.

An aeromycological study conducted in bathrooms, bedrooms and kitchens in Córdoba, Spain showed that highest concentrations of *Cladosporium* conidia were found in kitchens, followed by bathrooms and bedrooms [16]. In the present study, conidia concentrations of *Cladosporium* were highest in the kitchens, followed by bedrooms and bathrooms. Those differences were not significant. Since Infante-Garcia-Pantaleton & Dominguez-Vilches [16] did not use statistical methods to detect differences among the three rooms, we do not know whether any of the differences they recorded were significant. Gallup et al. [7]

found that highest counts of airborne fungal spores in residences sampled in California were in bathrooms, followed by living rooms, family rooms and bedrooms [7]. Three aspects that might have contributed to the differences of indoor aeromycota between those in Kitchener-Waterloo and California are biogeographic factors, sampler design, and methods of data analysis. Houses in California are drier and tend to have lower RH which could make humidity a critical factor. The samplers: Anderson sampler (viable method) and Rotorod sampler (impaction method) used by Gallup et al. [7] in California operated on a different principle and have different efficiencies than the Samplair sampler used in the present study.

House plants are sources of fungi: they are hosts of plant pathogenic and saprobic fungi, and potting soil is a substrate for soil fungi. Water drained or spilled from pots will cause dampness on carpet or floor and promote fungal growth. Malloy and Levetin [17] recorded 92.3 CFU/m^3 in rooms with potted plants in a hospital, significantly higher than the 20.8 CFU/m^3 recorded in rooms without potted plants. The highest fungal spore concentrations and the most house plants were found in living rooms in the present study. Burge et al. [18] found that watering and fan elevated conidia levels of *Cladosporium*, *Penicillium*, *Alternaria*, *Epicoccum* and *Pithomyces* in homes and greenhouses. The significance of house plant contributions to the indoor aeromycota needs to be further studied.

A lower temperature and a higher RH in family rooms in basements could be one of the factors contributing to dampness by water condensation. Since temperature and RH are negatively correlated [19], absolute humidity should be measured in future research to separate their effects.

The results of air conditioners in use are consistent with those observed by Solomon et al. [20] and Flannigan et al. [21]. If the condenser units of air conditioners were contaminated by fungi, they could generate adverse effects on the residents [2].

Carpet provides an ideal place for airborne fungal spores to settle and accumulate. It can also be a substrate for fungal growth. Within an hour of wetting, fungi will begin to reproduce in moist carpet [22]. It is difficult to eliminate these spores from the carpet by normal cleaning or vacuuming. Surface sampling of the carpet revealed moderate to heavy contamination despite relatively low airborne fungal spore concentrations [1]. Human activities, even normal walking on the carpet, could resuspend the spores and increase spore counts significantly [1]. It is understandable why spore counts of *Alternaria*, unidentified ascospores, unidentified basidiospores, *Cladosporium*, *Coprinus*, *Ganoderma*, unidentified spores, total spores and hyphal fragments were significantly greater in rooms with carpet than in those without carpet (Table 1).

The reason for our failure to report differences in symptoms with and without carpet was that in every residence sampled there was wall-to-wall carpet at least in the living room. Any room in the residence with a high spore count could be a triggering factor for allergenic respiratory disease.

Dampness is a common problem in houses. Even a few drops of water penetrating a leaky roof or wall will be enough for microorganisms to grow in surface dirt on insulation or on structural wood [22]. It is well known that in sufficiently moist conditions almost any material can become mouldy [23]. The reported prevalence of home dampness or moulds was approximately 38% in Canada [24–26] and approximately 55% in USA [12]. Varekamp & Leupen [27] reported that 80% of randomly surveyed homes in the Netherlands experienced dampness problems, indicated by the presence of moulds, visible dampness, or water damage.

Significantly greater spore counts of most airborne fungi except *Alternaria* and unidentified ascospores, and higher prevalence of allergic symptoms were found in damp residences during the present research. Waegemaekers et al. [28] also noted the similar results. Bravery [29] found that the spore counts in damp houses were over six times those in dry houses. Dampness permitted moulds to flourish [30], and damp and mouldy living conditions clearly have an adverse effect on symptomatic health [8]. The correlations between dampness and self-reported respiratory symptoms have been established in numerous studies [6, 8, 24–26, 31–37].

Air filters screen incoming air and eliminate some of airborne spora and dust from indoor air. Humidifiers are intended to make residents feel more comfortable in winter. Some of the air flow in the furnace is diverted through a constantly moistened rotating drum filter. This undoubtedly removes some of the airborne spores. It is not surprising, then, to find that some kinds of fungal spores were trapped in significantly lower numbers with humidifier. This was correlated with significantly reduced symptoms (Table 1).

Air movement indoors was accelerated by forced air heating systems. The resuspension of spores by forced air was diminished by the cleaning effects of the filter and humidifier. These factors contributed to the significant decrease in the spore counts of *Alternaria*,

Epicoccum, hyphal fragments and biodiversity, as well as significantly reduced symptoms.

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