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Original article

Indoor house dust-borne fungi and risk of allergic respiratory diseases in Baghdad city

Champignons véhiculés par la poussière domestique et risque de maladies respiratoires allergiques dans la ville de Bagdad

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ABSTRACT

Background. – Indoor allergens are important components of airborne allergens, and studies have linked allergic respiratory diseases (ARDs) and exposure to aeroallergens.

Objectives. – This study sought to identify fungi in house dust from four regions in Baghdad city, and to assess the risks of ARD and asthma associated with indoor fungi.

Methods. – House dust was collected from 84 homes located in four major areas in Baghdad; locations 1, 2, 3 and 4 (north, west, south-west and south of Baghdad, respectively). The dust samples were cultured to identify fungal genera.

Results. – Seventy-nine mold isolates belong to nine genera (*Aspergillus*, *Rhizopus*, *Penicillium*, *Chrysosporium*, *Mucor*, *Fusarium*, *Cladosporium*, *Alternaria* and *Helminthosporium*), as well as five yeast isolates, were identified. *Aspergillus* was the most common type of mold (56.0%), while *Alternaria* and *Helminthosporium* were the least frequent (each with 1%). The distribution of these fungi showed variation according to location, but the difference was not significant. ARD in general and asthma in particular were detected in 50.0 and 14.3% of households, respectively. Both types of allergy were significantly associated with mold genera and with the number of households and rooms, as well as the availability of gardens and trees.

Conclusions. – The study indicated that fungi are significant indoor determinants of ARD and asthma in the city of Baghdad.

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R É S U M É

Contexte. – Les allergènes intérieurs sont des composants importants des allergènes en suspension dans l'air et des études ont établi un lien entre les maladies respiratoires allergiques (MRA) et l'exposition aux aéroallergènes.

Objectifs. – Cette étude visait à identifier les champignons dans la poussière domestique de quatre régions de la ville de Bagdad et à évaluer les risques de MRA et d'asthme associés aux champignons intérieurs.

Méthodes. – La poussière domestique a été collectée dans 84 maisons situées dans quatre zones principales de Bagdad; emplacements 1, 2, 3 et 4 (nord, ouest, sud-ouest et sud de Bagdad, respectivement). Les échantillons de poussière ont été cultivés pour identifier les genres de champignons.

Résultats. – Soixante-dix-neuf isolats de moisissures appartiennent à neuf genres (*Aspergillus*, *Rhizopus*, *Penicillium*, *Chrysosporium*, *Mucor*, *Fusarium*, *Cladosporium*, *Alternaria* et *Helminthosporium*), ainsi que cinq isolats de levure ont été identifiés. *Aspergillus* était le type de moisissure le plus courant (56,0 %), tandis que *Alternaria* et *Helminthosporium* étaient les moins fréquents (chacun avec 1 %). La distribution de ces champignons a montré une variation selon l'emplacement, mais la différence n'était pas significative. La

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MRA en général et l'asthme en particulier ont été détectées dans 50,0 et 14,3 % des ménages, respectivement. Les deux types d'allergie étaient significativement associés aux genres de moisissures et au nombre de ménages et de pièces, ainsi qu'à la disponibilité de jardins et d'arbres.

Conclusions. – L'étude a indiqué que les champignons sont des déterminants intérieurs importants de la MRA et de l'asthme dans la ville de Bagdad.

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1. Introduction

In recent decades, the prevalence of allergic respiratory diseases (ARDs; asthma, rhinitis, urticaria, atopic dermatitis and food and drug allergies) has dramatically increased and may represent the most commonly encountered immunologically-based diseases [1]. Epidemiological and experimental investigations have suggested that exposure to airborne inhalants is associated with increased risk of developing ARDs [2]. Indoor allergens are important components of airborne allergens, and studies have linked allergic respiratory diseases (ARDs) and exposure to aeroallergens [3,4]. Further, it has been confirmed that sensitization to indoor allergens is strongly associated with risk of a wide range of ARDs [5]. Although the role of indoor allergen exposures in the development of allergic sensitization and progression of ARDs is complex and not fully understood, elevated indoor allergen levels in parts of the house, particularly bedrooms, can trigger and exacerbate symptoms in allergic and asthmatic individuals [6,7]. Many components of indoor allergens are fungi, and in a recent comprehensive study, their inhalation has been associated with a higher prevalence of asthma and wheezing [8]. Fungi are rich sources of numerous biologically active molecules with allergenic potential [9]. Further, fungal spores and fragments are able to spread throughout the air and due to their small size (less than 10 μm), they can penetrate deeply into the airways, and as a consequence, episodes of allergic reactions are generated [9].

Contact between fungal spores and human occurs in outdoor, indoor, and occupational environments; however, fungal exposure through inhalation in the indoor environment is of particular issue due to its association with increased sensitization to respiratory allergies including asthma [10]. Further, indoor fungal exposure and sensitization can exacerbate allergic diseases. In this context, numerous fungal genera have been associated with allergic respiratory diseases, such as *Aspergillus*, *Cladosporium*, *Alternaria* and *Penicillium* [11]. Therefore, residential exposure to these fungi might be expected because fungal spores and fragments can enter the indoor environment in multiple ways; for instance, through open windows and doors, as well as via clothing and pets [12]. In Iraq, a recent cross-sectional observational study examined the allergen profile in 653 rhinitis and 521 asthma patients. It was found that molds were the most sensitizing allergen in both groups of patients [13].

Due to the significance of fungi in ARD sensitization, this study examined the fungal profile in house dust obtained from houses located in four major regions in Baghdad city. ARD and asthma were also inspected in the participating households with the aim of evaluating their correlation with indoor fungi and other parameters (number of households and room facilities, and existence of gardens and trees).

2. Materials and methods

2.1. Study sites

Dust samples were collected from 84 urban homes located in four major regions in the city of Baghdad, Iraq, during April–May

2019. They were selected to represent different types of housing and family characteristics. Location 1 included a northern region (Al-Wazireya). Location 2 included three western regions (Hay Al-Jamiaa, Al-A'amiriya and Hay Huteen). Location 3 included six south-west regions (Alsaydia, Umm Al-Ma'alif, Al-Ray, Al-Shabab, Al-Alam and Al-Turath). Location 4 included a southern region (Al Rasheed district) (Fig. 1).

2.2. Dust sampling

As previously described [14], a single sample of dust was collected from the floor of the living area and bedroom during the course of the home visit. When the household home visit was scheduled, participants were asked to avoid cleaning their homes for 48 hours. The households were instructed to clean the areas mentioned for 15 minutes using a vacuum cleaner. The dust bag was then taken from the vacuum cleaner and the dust was retrieved and transferred to zipped sterilized polyethylene bags. In less than 12 hours, the plastic bags were shipped to the laboratory where the dust sample was sieved before processing, with hair and other large particles being removed, and then transferred to a sterile conical flask.

2.3. Isolation and identification of fungi

Based on a previously described protocol for cultivation, isolation and identification of fungi [15], 10 grams of dust sample was well suspended in 90 ml of sterile distilled water and mixed. One ml of the suspension was transferred and spread on potato dextrose agar (PDA) medium, and the plates were then incubated at 25 °C for seven days. After incubation, fungal colonies were identified at genus level by observing macro- and micro-morphological characteristics.

2.4. Questionnaire

A questionnaire was used from the European Community Respiratory Health Survey (ECRHS) [16] and the International Study of Asthma and Allergies in Childhood (ISAAC) [17] and was modified according to the study objectives. It contained questions on the history of asthma, as well as ARD symptoms. Respiratory symptoms were defined in this study as asthma as well as ARD (asthma and rhinitis). The questionnaire consisted of three sections. Section I pertained to personal factors and the home environment; location of your house in Baghdad city, how many rooms in the house, how many family members live in the house, and is there a garden in your house; if "yes", are there trees in the garden. Section II included questions regarding asthma symptoms; have you had wheezing or whistling in the chest at any time in the last 12 months, have you been at all breathless when the wheezing noise was present, have you had this wheezing or whistling when you did not have a cold, have you had an attack of shortness of breath that came on during the day while at rest at any time in the last 12 months, have you had an attack of shortness of breath that came on following strenuous activity at any time in the last 12 months, and have you ever been woken by an attack of shortness of breath in the last 12 months. In

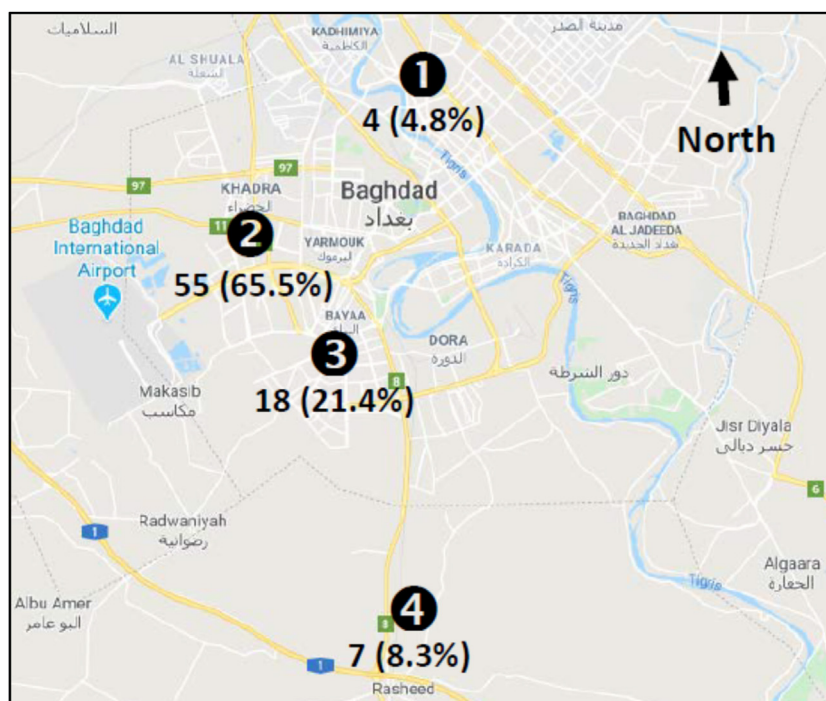


Fig. 1. Map of Baghdad depicting four study locations (circled numbers) with numbers and percentage sampling for each location.

addition, section II included questions on asthma evaluation; have you ever had asthma, was the asthma diagnosed by a physician, have you had any asthma attacks in the last 12 months, and are you currently using any asthma medication (spray, inhalation powders and/or tablets). Section III included questions related to rhinitis; do you have any nasal allergies (including hay fever), have you ever had a problem with sneezing, or a runny or a blocked nose when you did not have a cold or flu in the last 12 months, was this nose problem accompanied by itchy or watery eyes, and have you used any steroid nasal sprays, antihistamines pills, capsules or tablets to treat your nasal disorder in the last 12 months.

2.5. Statistical analysis

Data were given as either an absolute number and percentage frequency or as a mean $\pm$ standard deviation (SD). Significant differences between frequencies were assessed by Pearson Chi-square test or Fisher's Exact Test for two-tailed probability, while F-test was used to assess differences between means. Multinomial logistic regression analysis was applied to calculate odds ratios (OR) and 95% confidence intervals (CI). Linear regression analysis was employed to assess the impact of household/room ratio on type of fungi. Probability (p)-value ≤ 0.05 was considered statistically significant. The statistical package IBM SPSS Statistics 25.0 (Armonk, NY: IBM Corp.) was used to carry out these analyses.

3. Results

3.1. Baseline data

Baseline data of locations studied are given in Table 1. Out of all households (84 family), 14.3% had asthma, while 50% had signs and symptoms of ARD. Most cases were observed at locations 2, 3 and 4. For location 1, no asthma or ARD cases were found. The number of households varied between 2 and 11, but it was averaged in most location at 4 (total number = 343). For the sake of simplification, the number of households was limited to two groups; ≤ 4 and > 4

households. The ≤ 4 group recorded the highest frequency at the overall locations (81.3%) or at individual locations (100.0, 80.4, 83.3 and 71.4% for locations 1, 2, 3 and 4, respectively). The number of rooms in each home was similarly distributed: ≤ 4 and > 4 rooms. Again, group ≤ 4 outnumbered group > 4 in overall locations (82.1 vs. 17.9%) or locations 2, 3 and 4 (80.4 vs. 19.6, 83.3 vs. 16.7 and 71.4 vs. 28.6, respectively). For location 1, the four houses studied had > 4 rooms. Gardens were present in most houses in locations 2, 3 and 4 (69.9, 61.1 and 57.1%, respectively). Similarly, trees were also abundant in locations 2, 3 and 4 (67.3, 55.6 and 57.1%, respectively). Location 1 had neither gardens nor trees. The distribution of the parameters presented showed no significant variation between locations. The presence of trees was an exception, and there was a significant difference between the locations (p -value = 0.05), and this difference may be attributed to location 1.

3.2. Types of fungi

Cultivation of house dust samples identified 79 mold and five yeast isolates. The molds included nine genera; *Aspergillus*, *Rhizopus*, *Penicillium*, *Chrysosporium*, *Mucor*, *Fusarium*, *Cladosporium*, *Alternaria* and *Helminthosporium*, with a total frequency of 94.0%. *Aspergillus* was the dominant mold in total samples (56.0%), followed by *Rhizopus* (10.7%), *Penicillium* (7.1%), *Chrysosporium* (7.1%), *Mucor* (4.8%), *Fusarium* (3.6%), *Cladosporium* (2.4%), *Alternaria* (1.2%) and *Helminthosporium* (1.2%). These frequencies showed location-dependent differences, but no statistical significance was attained. The identified yeast isolates accounted for 6.0% of total dust samples. These isolates were identified in locations 2 and 3 with approximate frequencies (Table 2).

3.3. Location-based risk of asthma and allergic respiratory disease

Due to low sample size, locations 1 and 4 were incorporated in one group for the purpose of multinomial regression analysis. It was observed that households at location 2 were at greater risk of asthma, while households at location 3 were at greater risk of

Table 1
Baseline data of the locations studied.

Data ^a	Location				p-value
	1	2	3	4	
Asthma					
Yes	0 (0.0)	10 (18.2)	1 (5.6)	1 (14.3)	0.481
No	4 (100.0)	45 (81.8)	17 (94.4)	6 (85.7)	
Allergic respiratory disease					
Yes	0 (0.0)	29 (52.7)	9 (50.0)	4 (57.1)	0.230
No	4 (100.0)	26 (47.3)	9 (50.0)	3 (42.9)	
Number of households					
Mean $\pm$ SD	4.0 $\pm$ 0.0	4.5 $\pm$ 2.0	4.0 $\pm$ 0.8	4.4 $\pm$ 0.8	0.754
≤ 4	4 (100.0)	41 (80.4)	15 (83.3)	5 (71.4)	0.696
> 4	0 (0.0)	10 (19.6)	3 (16.7)	2 (28.6)	
Number of rooms					
Mean $\pm$ SD	4.0 $\pm$ 0.0	4.3 $\pm$ 1.0	4.1 $\pm$ 0.6	4.4 $\pm$ 0.7	0.567
≤ 4	4 (100.0)	44 (80.0)	16 (88.9)	5 (71.4)	0.542
> 4	0 (0.0)	11 (20.0)	2 (11.1)	2 (28.6)	
Gardens					
Yes	0 (0.0)	38 (69.9)	11 (61.1)	4 (57.1)	0.050
No	4 (100.0)	17 (30.9)	7 (38.9)	3 (42.9)	
Trees					
Yes	0 (0.0)	37 (67.3)	10 (55.6)	4 (57.1)	0.060
No	4 (100.0)	18 (32.7)	8 (44.4)	3 (42.9)	

p: Pearson Chi-square test or F-test probability; SD: Standard deviation.

^a Data are given as absolute numbers and percentage frequencies, unless otherwise specified.

Table 2
Isolated fungi (molds and yeasts) from house dust in the locations studied.

Fungus	N (%)				
	Total	Location			
		1	2	3	4
<i>Aspergillus</i>	47 (56.0)	4 (8.5)	29 (61.7)	10 (21.3)	4 (8.5)
<i>Rhizopus</i>	9 (10.7)	ND	7 (77.8)	1 (1.1)	1 (1.1)
<i>Penicillium</i>	6 (7.1)	ND	3 (50.0)	3 (50.0)	ND
<i>Chrysomya</i>	6 (7.1)	ND	5 (83.3)	1 (16.7)	ND
<i>Mucor</i>	4 (4.8)	ND	3 (75.0)	ND	1 (25.0)
<i>Fusarium</i>	3 (3.6)	ND	1 (33.3)	1 (33.3)	1 (33.3)
<i>Cladosporium</i>	2 (2.4)	ND	2 (100.0)	ND	ND
<i>Alternaria</i>	1 (1.2)	ND	1 (100.0)	ND	ND
<i>Helminthosporium</i>	1 (1.2)	ND	1 (100.0)	ND	ND
Yeast	5 (6.0)	ND	3 (60.0)	2 (40.0)	ND

ND: not detected.

Table 3
Risk of asthma and allergic respiratory disease in association with the study location.

Parameter	Reference category	Asthma		Allergic Respiratory Disease	
		OR (95% CI)	p-value	OR (95% CI)	p-value
Location 2	Locations 1 + 4	2.53 (0.14–43.12)	0.520	1.25 (0.26–5.84)	0.774
Location 3		0.30 (0.01–11.13)	0.519	2.15 (0.39–11.72)	0.375

OR: Odds ratio; CI: Confidence interval; p: Multinomial logistic regression analysis probability adjusted for household/room ratio.

ARD (versus locations 1 + 4), but the *p*-values were not significant (Table 3).

3.4. Relation of asthma and ARD to fungal and household parameters

Asthma and ARD cases were distributed according to the parameters given in Table 4. Most cases of asthma and ARD were associated with molds (14.3 and 44.1%, respectively). However, ARD was further associated with yeast. The risk of asthma and ARD was mostly associated with other molds compared to *Aspergillus* (OR = 0.10 and 0.01; *p*-value = 0.003 and 0.001, respectively). Households and rooms ≤ 4 were negatively associated with asthma and ARD (i.e. decreased risk), and the difference

was significant (*p*-value = 0.04–0.001). However, gardens and trees contributed significantly to increased risk of asthma (OR = 8.78 and 9.85; *p*-value = 0.003, respectively), and much more greatly increased risk was observed in ARD (OR = 114.55 and 149.33; *p*-value = 0.001, respectively) (Table 4).

4. Discussion

Around the world, urbanization has impacted the social life of human populations, and most people, especially children and the elderly, spend around 90% of their daily lives inside their homes. The home environment represents a typical indoor environment that is regarded as a complex ecosystem harboring different microorganisms [18]. These microorganisms can adversely impact human

Table 4
Distribution of asthma and allergic respiratory disease according to certain parameters.

Parameter	Asthma					Allergic Respiratory Disease						
	Yes		No		<i>p</i> -value	OR (95% CI)	Yes		No		<i>p</i> -value	OR (95% CI)
	<i>N</i>	%	<i>N</i>	%			<i>N</i>	%	<i>N</i>	%		
Fungi												
Molds	12	14.3	67	79.8	0.906	2.04 (0.14–30.62)	37	44.1	42	50	0.055	0.22 (0.03–1.64)
Yeast	0	0	5	5.9			5	5.9	0	0		
Molds												
<i>Aspergillus</i>	2	2.5	45	57	0.003	0.10 (0.02–0.48)	5	6.3	42	53.2	0.001	0.01 (0.00–0.04)
Others	10	12.7	22	27.8			32	40.5	0	0		
Households												
≤ 4	1	1.3	64	80	0.001	0.01 (0.00–0.05)	23	28.7	42	52.5	0.001	0.04 (0.01–0.30)
> 4	11	13.7	4	5			15	18.8	0	0		
Rooms												
≤ 4	0	0	69	82.1	0.001	0.01 (0.00–0.05)	27	32.1	42	50	0.001	0.05 (0.01–0.35)
> 4	12	14.3	3	3.6			15	17.9	0	0		
Gardens												
Yes	12	14.3	41	48.8	0.003	8.78 (1.12–68.96)	42	50	11	13.1	0.001	114.55 (14.49–905.33)
No	0	0	31	36.9			0	0	31	36.9		
Trees												
Yes	12	14.3	39	46.4	0.003	9.85 (1.25–77.41)	42	50	9	10.7	0.001	149.33 (18.55–1202.01)
No	0	0	33	39.3			0	0	33	39.3		

p: Fisher's Exact Test for two-tailed probability; OR: Odds ratio; CI: Confidence interval.

health by acting as infectious pathogens, such as bacteria, or may induce allergic reactions, such as fungi, and it is well-recognized that the airborne bacteria and fungi are associated with different human morbidities [19,20]. Further, a substantial body of evidence has strengthened the view that early exposure to indoor microorganisms is considered a risk factor for chronic inflammations and allergies [21]. Therefore, investigating the profile of fungi in house dust may represent an important approach to evaluating the association between fungi and allergic episodes in the indoor environment.

The present study demonstrated that fungi, especially molds, were abundant in the examined samples of house dust. Notably, *Aspergillus* dominated the profile of molds, accounting for over 50% of molds isolated from most of the locations investigated. *Aspergillus* may thus represent a recognized burden of molds in house dust. Previously, it has also been demonstrated that *Aspergillus* is considered among the commonest genera found in house dust [18]. A further worldwide survey of mycobiota in house dust obtained from nine countries confirmed this abundance of indoor *Aspergillus* [22]. These two studies also showed *Penicillium* to be a further common genus in house dust. In the present study, *Penicillium* was also relatively common but it was ranked as the third among the profile of molds in house dust. The study also disclosed the existence of further mold genera in the collected house dust samples (*Rhizopus*, *Chrysosporium*, *Mucor*, *Fusarium*, *Cladosporium*, *Alternaria* and *Helminthosporium*), but their frequencies had a range of 1.2–10.7%. Consistently with these findings, it has been reported that indoor dust contains around 15 genera of fungi [23,24]. In most studies, these fungal genera were associated with an increased risk of ARDs and asthma [5,10–12,25].

Following these leads, households at 84 sites were screened for asthma and ARD according to the principles presented in the questionnaire used [16,17]. Applying these principles revealed that 14.3% of households had occupants with asthma, while in 50.0%, symptoms of ARD were recorded. In both cases, a probable association with molds was found. This may suggest that indoor molds constitute prominent risk factors for ARD. To assess which mold was more frequently associated with asthma or ARD, the identified household cases were distributed according to the genus of mold, considering *Aspergillus* in the first group and the other molds in the second group. It was noticed that most cases of asthma and ARD were associated with molds other than *Aspergillus*, although the

latter was most frequently recorded. Therefore, although the other mold genera had a lower frequency, they substantially influenced the risk of asthma and ARD in the investigated locations. These findings are supported by the report of the World Health Organization (WHO), in which it has been demonstrated that moldy houses exacerbate the risk of asthma [26]. Further, a great number of molds (approximately 80 mold genera) have been described in relation to induction of type I allergies in predisposed individuals [27]. Activation of adaptive immune responses due to sensitization to molds or their products has been suggested to be a cornerstone in mediating the deleterious allergic reactions [28]. A better understanding of antifungal immunity in the respiratory airways has also been gained. Fungi are delineated according to their content of important immunogenic components such as β -glucan and chitin (cell-wall molecules), in addition to which they secrete biologically active enzymes, e.g. proteases and glycosidases [29]. In turn, epithelial cells and innate immune cells (i.e. dendritic cells) in the respiratory airways are provided with cell-surface molecules that are able to react to these fungal products. As a consequence, cytokines and proinflammatory mediators are produced and activate T-helper cells that enhance protection against fungal infection, but at the same time lead to detrimental immunopathological changes in the respiratory airways of susceptible subjects [30].

In addition to fungi, household parameters (number of individuals and room facilities) acted as further risk factors for ARD and asthma. More home dwellers and less space were associated with a greater likelihood of developing allergies. It is suggested that home environmental factors influence the occurrence of ARD. Housing factors such as crowding status have been associated with allergic rhinitis [31]. It has further been suggested that the manifestation and presentation of asthma are strongly affected by various personal and household factors [32]. In addition, this study highlighted that inhabitants of houses with garden facilities, especially those with trees, were also at substantial risk of developing ARDs. Gardens and trees are a major source of specific aeroallergens. Among these are pollen allergens that come mainly from plants in gardens (trees, grasses and weeds) [33]. In the last decades, there has been an increased use of ornamental plants in gardens; therefore, new sources exist of aeroallergens that can be introduced into the indoor environment. Combined exposure to these aeroallergens and fungi may have a synergistic or additive effect on elevating the risk of asthma and ARDs [34].

5. Conclusions

The results of this study indicate that exposure to indoor environment is associated with an elevated risk of ARD and asthma. A synergistic or additive effect of indoor fungal allergens, house facilities and outdoor plant allergens is also thought to play a role in the occurrence of allergic disease.

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Disclosure of interest

The authors declare that they have no competing interest.

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