PYROGLYPHID MITES AS A SOURCE OF WORK-RELATED ALLERGENS

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Pyroglyphid mites are primarily associated with allergen exposure at home; hence the name house dust mites. However, we have found numerous studies reporting pyroglyphid mite levels in public and occupational settings. This review presents the findings of house dust mite allergens (family Pyroglyphidae, species Dermatophagoides) as potential work-related risk factors and proposes occupations at risk of house dust mite-related diseases. Pyroglyphid mites or their allergens are found in various workplaces, but clinically relevant exposures have been observed in hotels, cinemas, schools, day-care centres, libraries, public transportation (buses, trains, taxis, and airplanes), fishing-boats, submarines, poultry farms, and churches. Here we propose a classification of occupational risk as low (occasional exposure to mite allergen levels up to 2 μg g⁻¹), moderate (exposure between 2 μg g⁻¹ and 10 μg g⁻¹), and high (exposure >10 μg g⁻¹). The classification of risk should include factors relevant for indoor mite population (climate, building characteristics, and cleaning schedule). To avoid development or aggravation of allergies associated with exposure to house dust mites at work, occupational physicians should assess exposure risk at work, propose proper protection, provide vocational guidance to persons at risk and conduct pre-employment and periodic examinations to diagnose new allergy cases. Protection at work should aim to control dust mite levels at work. Measures may include proper interior design and regular cleaning and building maintenance.

KEY WORDS: allergic diseases, Dermatophagoides species, Der f 1, Der p 1, indoor allergens, occupational exposure, work-related diseases

Dust mites are an important source of potent allergens that can start a specific immunological reaction known as immunoglobulin E (IgE)-mediated allergic reaction or allergic reaction type I. This reaction is at the root of atopic diseases including atopic rhinitis, conjunctivitis, dermatitis, and asthma (1-3).

Even though experts are not unanimous about threshold allergen levels, they all acknowledge a dose-response relationship between dust mite allergen exposure and sensitisation and symptoms of related atopic diseases. However, 2 μg of dust mite allergen or 100 mites per gram of dust are commonly accepted as threshold levels for sensitisation in humans, while 10 μg of dust mite allergen or 500 mites per gram of dust are accepted as threshold levels for the occurrence of symptoms in already sensitised persons (1, 4, 5).

Therefore, monitoring exposure to dust mite allergens is an important part of the atopic diseases prevention. Over the years, several methods have been involved to measure dust mite allergen levels in various indoor dust samples. Historically the first method was the so called biological method with microscopic identification and scoring. Mites were usually separated from the dust using the flotation method (6) and were identified with identification keys.
Dermatophagoides pteronyssinus (D. pteronyssinus) is the main allergen of warmer climates that favour their growth (14-16). Levels of Der p 1 and Def f 1 (main allergens of D. pteronyssinus and D. farinae, respectively) increase from the north to the south European regions; in Scandinavian households they are virtually undetectable, while in Italy, Germany, Spain (16), and Croatia (17) they exceed the sensitisation threshold, in coastal households in particular.

The most common dust mites in households are from the Pyroglyphidae family, genera Dermatophagoides (D. pteronyssinus, D. farinae), hence the name “house dust mites”. Allergy to these mites is frequent in asthmatic patients (45 % to 90 %) and correlates with exposure, which is greater in occupational settings, and is still used for screening indoor exposure to dust mites. For more precise monitoring however, today we use the two-site monoclonal antibody-based enzyme immunoassay (9), either as a standard quantitative laboratory method (10) or its quicker, semi-quantitative immunodot versions like Dustscreen, Aclotest, or Ventia (11-13).

EXPOSURE TO HOUSE DUST MITES IN PUBLIC/OCCUPATIONAL SETTINGS

With the exception of house dust mite exposure in schools and day care centres, which are addressed further in the text, Table 1 shows exposure levels to pyroglyphid mites in public places reported by 32 studies from all over the world. Exposure to pyroglyphid mites in offices reported by seven studies from Italy, USA, Canada, Brazil, China, and New Zealand (20-26) was generally below the sensitisation threshold. Two studies (20, 21) reported that up to 5 % of dust samples had allergen levels above the 2 μg g⁻¹, mostly from upholstered office chairs. Three studies established a correlation between higher mite allergen levels and carpeted floors (21, 23, 24).

Hospitals were explored for house dust mites in five studies from Germany, New Zealand, USA, UK, and Poland (24, 27-30) including dust samples from hospital beds. None observed exposure above the sensitisation threshold, even in bed dust samples.

In contrast, hotel rooms in Brazil and New Zealand (24, 31) were highly contaminated with house dust mites; most floor and bed dust samples had the allergen level above the 2 μg g⁻¹. In fact, Brazilian hotel dust samples had allergen levels above the threshold level for symptom development.

Similarly high exposure to pyroglyphid mites was found in Polish and US libraries (28, 32) and in New Zealand and UK cinemas (24, 33); most dust samples exceeded the sensitisation threshold. In Polish libraries, the main source of mites were bookshelves, books, and upholstered chairs. In the US study, clinically significant allergen levels were found only in school libraries of southern states with warmer and more humid climate. The main sources of dust mite allergens in cinemas were upholstered chairs, and their levels rarely exceeded the symptom threshold.

Exposure to pyroglyphid mites was also investigated in buses, trains, trams, taxies, and airplanes in New Zealand, Finland, UK, Japan, and Brazil (24, 34-37). In UK trains (35) and Finnish buses, trams, and trains (34) it was very low. In New Zealand airplanes it was also very low, with the exception of a few seat samples above the sensitisation threshold (24). In contrast, Brazilian buses and Japanese trains were highly contaminated with pyroglyphid mites, with most dust samples above the sensitisation threshold (36, 37).

Pyroglyphid mite allergen levels above the sensitisation and symptom thresholds were observed in the bed dust from fishing boats and submarines (38,
39) occupied over long periods of time (three weeks for fishing boats, and three months for submariners).

Animal facilities, including experimental laboratories, zoo cages, and pig and poultry farms studied in Germany, Poland, Finland, and Croatia showed generally low exposure to pyroglyphid mites (40-42), save for a few poultry farm samples exceeding the sensitisation threshold (43).

Pyroglyphid mites were not found in outdoor communal waste in Poland (44), nor in Finnish groceries (45). Dust samples from churches in New Zealand showed mite allergen levels above the sensitisation threshold (24).

Exposure to pyroglyphid mites in schools and day care centres was addressed in two recently published reviews (46, 47). They confirm the correlation between exposure above the sensitisation threshold and warm/humid climate. High allergen levels also correlated with dampness, carpeting, fabric-covered furniture, bedding, and soft toys, as well as with poor cleaning practice. However, even in these circumstances mite allergen levels rarely exceed the symptom threshold.

ASSESSMENT OF OCCUPATIONAL EXPOSURE TO HOUSE DUST MITES

Undoubtedly the main source of exposure to pyroglyphid mites and their allergens are our homes, our bedrooms in particular. The highest mite allergen levels were observed in mattresses, pillows, carpets, and other textile-covered parts of households furniture, curtains, tapestry, and fabric wallpapers (16, 46). Mite population density and the corresponding level of allergens depend significantly on feeding options and indoor temperature and humidity. Households usually provide optimal conditions as far as feeding and indoor temperature go, but humidity may greatly limit mite population growth. Most house dust mites cannot grow in relative humidity below 50 %, particularly in households using central heating systems (17). In addition to climate, mite growth is favoured by dampness, poor ventilation, fabric furnishing, and poor cleaning practice (16, 46, 48).

Even though our homes are the main sources of exposure to pyroglyphid mites, there is enough evidence that house dust mites are present in numerous public and/or occupational indoor environments (Table 1). Mites can be transferred to a public place or a workplace on the clothes (49-51), skin, or hair, and will form an active population if the new environment provides favourable feeding opportunities, temperature, and humidity. Fabric furnishing, poor ventilation, dampness, and poor cleaning practice only add to occupational exposure. According to all that, pyroglyphid mites or their allergens are found in various workplaces like hotels, cinemas, schools, day-care centres, libraries, offices, public transportation (buses, trams, trains, cars), airplanes, fishing-boats, submarines, poultry farms, churches, hospitals, zoos-gardens, experimental laboratories, groceries (Table 1) (20-47).

In the occupational environments that do favour mite growth, risk assessment should first establish if the level of exposure is above the sensitisation and symptom thresholds (4). This is why we propose that the risk be classified in three categories: low risk generally involves exposure to levels below the sensitisation threshold with occasional exposure above 2 μg g⁻¹ or 100 mites per gram of dust; moderate risk involves exposures generally between the sensitisation and symptom thresholds [(2 to 10) μg g⁻¹ or (100 to 500) mites per gram of dust]; and high risk exposure mainly above the symptom threshold (>10 μg g⁻¹ or >500 mites per gram of dust). Based on the presented literature, in Table 2 we propose occupations at risk for clinically relevant occupational exposure to pyroglyphid mites in temperate climate. This classification should reflect relevant indoor conditions that may significantly affect occupational exposure (16, 46-48).

Another issue is establishing the relation between occupational exposure to pyroglyphid mites and the diagnosed allergic disease (rhinitis, asthma, or dermatitis). In the majority of cases, people are sensitised to dust mites at home and develop related allergic diseases in the childhood or adolescence. Their condition can only get worse at moderate-to-high-risk workplaces with exposure above the symptom threshold (10 μg g⁻¹). This is where the occupational health service can help by providing vocational/pre-employment counsel to pupils, students, and workers with allergic disease caused by house dust mites (52).

On the other hand, there are cases when allergic diseases caused by dust mites occur in adulthood after employment at risk workplaces (such as those proposed in Table 2). In temperate climates, residential exposure to house dust mites is by far more common than occupational, but workplaces with moderate and high exposures to pyroglyphid mites could substantially
### Table 1  Studies investigating exposure to house dust mites in various occupational settings

<table>
<thead>
<tr>
<th>Study (reference number)</th>
<th>Sampling place</th>
<th>Method and number of samples</th>
<th>House dust mites number or allergen levels</th>
<th>Percent of samples above the sensitisation threshold*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Janko et al., 1995 (26)</td>
<td>Offices (14 offices)</td>
<td>ELISA</td>
<td>Der p 1: &gt;1 μg g⁻¹ in 4 offices</td>
<td>None</td>
</tr>
<tr>
<td>Wickens et al., 1997 (24) New Zealand</td>
<td>Offices (banks)</td>
<td>ELISA 26 floor samples</td>
<td>Der p 1(IQR): (0.05 to 0.25)μg g⁻¹; GM 0.11 μg g⁻¹</td>
<td>None</td>
</tr>
<tr>
<td>Menzies et al., 1998 (22) Canada</td>
<td>Offices (from 6 office buildings)</td>
<td>ELISA Number of floor samples not presented</td>
<td>Der p 1 or Der f 1 levels ≥ 1 μg g⁻¹ attributable for 8% of work-related symptoms in exposed workers</td>
<td></td>
</tr>
<tr>
<td>Graudenz et al., 2002 (23) Brazil</td>
<td>Offices (from 3 office buildings)</td>
<td>ELISA</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Perfetti L et al., 2004 (20) Italy</td>
<td>Offices Bank archive</td>
<td>ELISA (Dustscreen™) 160 floor or chair samples, 41 from archive</td>
<td>Der p 1 (IQR): (0.05 to 0.25) μg g⁻¹; max. 19.5 μg g⁻¹</td>
<td>Der p 1: 5% of samples</td>
</tr>
<tr>
<td>Macher et al., 2005 (21) USA</td>
<td>Offices (from 92 office buildings)</td>
<td>ELISA 251 floor samples</td>
<td>Detectable levels of Der p 1 and Der f 1 in 78% of samples</td>
<td>Der f 1: 4% of samples, Mostly from upholstered chairs</td>
</tr>
<tr>
<td>Dong and Yao, 2010 (25) Beijing, China</td>
<td>Office, hospital, subway, train station</td>
<td>ELISA</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Babe et al., 1995 (30) USA</td>
<td>Hospital</td>
<td>Microscopic counting 120 floor samples from carpeted and noncarpeted rooms and hallways</td>
<td>Number of mites, <em>D.pteronyssinus</em> and <em>D.farinae</em>: Range: (0 to 143) mites per gram; Mean: 28 mites per gram (carpeted rooms)</td>
<td>Only 1 sample from noncarpeted room</td>
</tr>
<tr>
<td>Wickens et al., 1997 (24) New Zealand</td>
<td>Hospitals</td>
<td>ELISA 19 floor samples 15 bed samples</td>
<td>Der p 1: Floor: IQR (0.04 to 0.51) μg g⁻¹; GM 0.14 μg g⁻¹ Bed: IQR (0.02 to 0.47) μg g⁻¹; GM 0.10 μg g⁻¹</td>
<td>None</td>
</tr>
<tr>
<td>Solarz et al. 1998 (28) Poland</td>
<td>Hospitals</td>
<td>Microscopic counting 122 floor or bed samples</td>
<td>Number of mites (range): Floor: (1 to 100) mites per gram Bed: (2 to 100) mites per gram Proportion of pyroglyphid mites: 57.5%</td>
<td>None</td>
</tr>
<tr>
<td>Ćustović et al. 1998 (29) UK</td>
<td>Hospitals</td>
<td>ELISA 83 carpet samples 69 bed samples 42 upholstered chairs</td>
<td>Der p 1</td>
<td>None</td>
</tr>
<tr>
<td>Eberlein et al. 2009 (27) Germany</td>
<td>Hospitals</td>
<td>ELISA 30 bed samples</td>
<td>Der p 1 (IQR): (0 to 0.2) μg g⁻¹; Der f 1 (IQR): (0.15 to 0.8) μg g⁻¹</td>
<td></td>
</tr>
<tr>
<td>Wickens et al., 1997 (24) New Zealand</td>
<td>Hotels</td>
<td>ELISA 15 floor samples 15 bed samples</td>
<td>Der p 1: Floor: IQR (2.06 to 13.41) μg g⁻¹; GM 5.26 μg g⁻¹ Bed: IQR (1.54 to 8.28) μg g⁻¹; GM 3.57 μg g⁻¹</td>
<td>Majority of samples</td>
</tr>
</tbody>
</table>
### Table 1

<table>
<thead>
<tr>
<th>Study (reference number)</th>
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<th>Percent of samples above the sensitisation threshold*</th>
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</table>
| Simplicio et al., 2007 (31) Brazil | Hotels | ELISA 42 carpet samples 98 bed samples | Der f 1: Floor: IQR (4.31 to 9.26) μg g⁻¹; GM 6.3 μg g⁻¹  
Bed: IQR (8.34 to 15.30) μg g⁻¹; GM 11.30 μg g⁻¹  
Der p 1: Bed: IQR (0.13 to 0.18) μg g⁻¹; GM 0.15 μg g⁻¹ | Der f 1 in all samples  
Der f 1 levels > 10 μg g⁻¹; (58 to 76) % of samples |
| Solarz et al. 1998 (28) Poland | Libraries | Microscopic counting 14 chairs, desks, bookshelves or book samples | Number of mites (range):  
Chairs: (10 to 400) mites per gram  
Book-shelves and books: (250 to 400) mites per gram  
Desks: (1 to 14) mites per gram  
Proportion of pyroglyphid mites: 79 % | Majority of chair samples  
All samples from bookshelves and books |
| Abramson et al., 2006 (32) USA | School libraries (41 primary schools from 3 geographical regions) | ELISA 50 floor samples | Der p 1 (median):  
Southeast region: 2.5 μg g⁻¹  
Midwest region: 0.03 μg g⁻¹  
Southwest region: 7.5 μg g⁻¹ | Majority of samples from southeast and southwest region |
| Custović et al. 1994 (33) UK | Cinemas | ELISA seat samples | Der p 1 | 30 % of samples  
Der p 1 levels > 10 μg g⁻¹; 9 % of samples |
| Wickens et al. 1997 (24) New Zealand | Cinemas | ELISA 13 floor samples 10 seat samples | Der p 1:  
Floor: IQR (0.54 per 2.26) μg g⁻¹; GM 1.11 μg g⁻¹  
Seat: IQR (2.58 to 14.51) μg g⁻¹; GM 6.12 μg g⁻¹ | Majority of seat samples |
| Wickens et al. 1997 (24) New Zealand | Churches | ELISA 29 floor samples | Der p 1:  
IQR (0.71 to 3.34) μg g⁻¹; GM 1.54 μg g⁻¹ | Minority of samples |
| Engelhart et al. 1999 (39) Germany | 2 submarines A in harbour for 3 months B cruising for 3 months | ELISA 28 bunk mattress samples | Der p 1+Der f 1:  
A submarine: < 0.5 μg g⁻¹  
B submarine: median 4.4 μg g⁻¹ | A submarine: none  
B submarine: 73 % of samples |
| Macan et al. 2005 (38) Croatia | Fishing boats | ELISA (Dustscreen™) 5 samples from cabin floor 5 samples from cabin beds | Der p 1:  
Floor: range (0 to 0.65) μg g⁻¹; median 0.05 μg g⁻¹  
Bed: range (0.1 to 15) μg g⁻¹; median 10 μg g⁻¹ | Majority of bed samples |
| Colloff MJ 1986 (35) UK | Trains | Microscopic counting 16 upholstered seat samples 6 samples from stored blankets and pillows | Number of mites in 22 samples (range): (4 to 12) mites per gram  
Proportion of pyroglyphid mites: 55 % | None |
| Wickens et al. 1997 (24) New Zealand | Airplanes | ELISA 14 floor samples 14 seat samples | Der p 1:  
Floor: IQR (0.18 to 0.47) μg g⁻¹; GM 0.29 μg g⁻¹  
Seat: IQR (0.89 to 2.93) μg g⁻¹; GM 1.62 μg g⁻¹ | Minority of seat samples |
<p>| Uehara et al. 2000 (36) Japan | Trains | Modification of ELISA 10 μg of antigen = 100 mites 492 seat and bed cloth samples | Monoclonal antibody against D. farinae or D. pteronyssinus | Most samples &gt;100 mites per square meter |</p>
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</tr>
</thead>
<tbody>
<tr>
<td>Partti-Pellinen et al., 2000 (34) Finland</td>
<td>Trains, buses, and trams</td>
<td>ELISA 18 floor and seat samples</td>
<td>Der p 1, Der m 1: &lt; 0.05 μg g⁻¹; Der f 1: not detectable</td>
<td>None</td>
</tr>
<tr>
<td>Pereira et al. 2004 (37) Brazil</td>
<td>Buses, taxies</td>
<td>ELISA 120 seat samples from buses 60 seat samples from taxies</td>
<td>Der p 1 and Der f 1</td>
<td>Der p 1: 82 % of bus samples; Der f 1: 58 % of bus samples</td>
</tr>
<tr>
<td>Radon et al. 2000 (42) Germany</td>
<td>Pig-farms (100)</td>
<td>ELISA 500 samples: 300 confinement samples, 100 transit area sample, 100 farmer mattress sample</td>
<td>Der p 1: Confinement samples: range (0 to 3.3) μg g⁻¹; median 0 Transit area samples: range (0 to 10) μg g⁻¹; median 0.2 μg g⁻¹ Farmer mattress samples: range (0 to 774) μg g⁻¹; median 53.4 μg g⁻¹</td>
<td>None for confinement samples</td>
</tr>
<tr>
<td>Pennanen et al. 2003 (40) Finland</td>
<td>Laboratory animal facilities</td>
<td>Microscopic counting 20 samples from floor, animal cages, food, bedding, lounge chairs ELISA 4 samples</td>
<td>44 and 56 mites per gram (median) Only one pyroglyphid mite in a chair sample</td>
<td>Der p 1: 0.002 μg g⁻¹ in one of the 4 allergen samples</td>
</tr>
<tr>
<td>Solarz et al. 2004 (41) Poland</td>
<td>Zoo cages</td>
<td>Microscopic counting 49 cage samples (dust, litter, debris, residue)</td>
<td>D. farinae: &lt; 1 % of total mite fauna</td>
<td>None</td>
</tr>
<tr>
<td>Rimac et al. 2010 (43) Croatia</td>
<td>Poultry farms</td>
<td>ELISA 17 floor and cage samples</td>
<td>Der p 1: range (&lt;0,10 to 3.30) μg g⁻¹; median 0.78 μg g⁻¹</td>
<td>Minority of cage samples</td>
</tr>
<tr>
<td>Solarz et al. 2007 (44) Poland</td>
<td>Outdoor communal waste</td>
<td>Microscopic counting 86 samples of litter soiled with communal waste</td>
<td>No pyroglyphid mites found</td>
<td>None</td>
</tr>
<tr>
<td>Harju et al. 2006 (45) Finland</td>
<td>Groceries (storage and sales rooms)</td>
<td>Microscopic counting 56 samples from cashier’s chair, floor and pet aisles, fruit/vegetable section, bread counter ELISA 14 samples from cashier’s chair, floor aisle, storage area</td>
<td>One sample out of 14 contained detectable levels of Der p 1 [80 times smaller than the concentration suggested causing sensitization (2 μg g⁻¹)] and none had detectable Der f 1 levels</td>
<td>None</td>
</tr>
</tbody>
</table>

* sensitisation threshold: >2 μg of mite allergen or >100 mites per gram of dust.
IQR: interquartile range; GM: geometric mean; ND: not detectable; Der m 1: main allergen of D. microceras

Contribute to the development of sensitisation and allergic disease, which can be categorised as work-related disease, that is, disease partially caused by workplace. In such cases, occupational physicians should be able to establish this relation. This should involve measurement of exposure at home and at work, and if a work-related disease is established, these workers should be entitled to benefits provided by local laws.
To prevent sensitisation or aggravation of allergic disease, occupational physicians should design pre-employment examinations and regular health surveillance to include occupational exposure to dust mites (52). Preventive action should also involve control of dust mite population at work through the use of fibreless furnishing, proper building maintenance, ventilation, heating, and regular cleaning (16, 46-48). These measures should be strictly implemented, particularly in hotel rooms, fishing boat cabins, or submarines with beds (24, 31, 38, 39).

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PIROGLIFIDNE GRINJE (PYROGLYPHIDAE) KAO IZVOR PROFESIONALNIH ALERGENA

Piroglifidne gringe smatraju se prvenstveno izvorom alergena u našim domovima. Postoji, međutim, sve više studija koje upućuju na izloženost piroglifidnim grinja u javnim i radnim prostorima. Cilj je ovog pregleda prikazati alergene piroglifidnih grinjaka kao potencijalne štetnosti vezane uz radna mjesta i utvrditi rizična zanimanja za pojavu i progresiju bolesti uzrokovanih piroglifidnim grinja. Iz baze PubMed izdvojene su studije koje su istraživala izloženost piroglifidnim grinja (porodica Pyroglyphidae, rod Dermatophagoides) u različitim javnim i radnim prostorima. Piroglifidne gringe ili njihovi alergeni pronađeni su na različitim radnim mjestima, ali klinički značajne izloženosti zabilježene su u hotelima, kinima, školama, vrtićima, knjižnicama, vozilima (autobusima, vlakovima, taksi-vozilima), avionima, ribarskim brodovima, podmornicama, peradarnicima i crkvama. Predloženo je stupnjevanje rizika na radnim mjestima sa značajnom izloženosti alergenima piroglifidnih grinja kao niskog (povremena izloženost razinama >2 μg g⁻¹), umjerenog (izloženost pretežno između 2 μg g⁻¹ i 10 μg g⁻¹) i visokog rizika (izloženost pretežno >10 μg g⁻¹). Pri procjeni razine rizika treba uvijek uzeti u obzir čimbenike koji značajno utječu na populaciju grinja (klimatska regija, karakteristike zgrade, način čišćenja). Specijalisti medicine rada trebali bi razmotriti moguću profesionalnu izloženost piroglifidnim grinja pri procjeni opasnosti za radna mjesta i provedbi mjera zaštite na radu, pri profesionalnoj orijentaciji, prethodnim i periodskim pregledima te dijagnostici bolesti vezanih uz rad, u svrhu prevencije pojave ili pogoršanja alergijskih bolesti uzrokovanih piroglifidnim grinja. Mjere zaštite na radu trebaju biti usmjerene kontroli populacije grinja na radnom mjestu, uključujući odgovarajuće uređenje interijera, te redovito čišćenje i održavanje zgrade.

KLJUČNE RIJEČI: alergeni unutarnjih prostora, alergijske bolesti, bolesti vezane uz rad, Dermatophagoides species, Der p 1, Der f 1, profesionalna izloženost

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