HOUSE-DUST MITES: CHALLENGES WITH ESTABLISHING CAUSAL ASSOCIATIONS IN OCCUPATIONAL HEALTH FOR UBIQUITOUS AGENTS – A RETROSPECTIVE STUDY

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ABSTRACT

In this retrospective study, the sensitisation profiles of 846 workers (≥18 years old) were tested with house-dust mite (HDM) allergens and other common aeroallergens for the ten-year period 2002–2022. This study aimed to determine the proportion of HDM sensitisation among workers from various industries and to highlight the role of HDM exposure and current developments in occupational settings. Exposure to HDM allergen can occur in both households and work environments. *Dermatophagoides farinae* and *Dermatophagoides pteronyssinus* are the most commonly distributed dust mites worldwide. Inhaling allergens produced from these mites can result in respiratory symptoms, rhinitis and asthma in sensitised individuals. Exposure to these allergens in the workplace may result in occupationally acquired or work-aggravated allergic reactions, leading to poor quality of life, an increase in absenteeism arising from sickness and, consequently, reduced productivity. The percentage sensitisation among workers referred to the NIOH Occupational Allergy clinic was 41.67% for *D farinae* and 33.81% for *D pteronyssinus*. Nineteen per cent of the patients who reported work-related symptoms tested positive for HDM; therefore, work-related sensitisation is plausible. While *Blomia tropicalis* was not tested in the current study, it may be beneficial in tropical areas.

Keywords: house-dust mite allergy, asthma, occupational exposure, occupational risk

INTRODUCTION

House-dust mites (HDM) belong to the *Pyroglyphidae* family[1–3] and include *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, *Euroglyphus maynei* and *Blomia tropicalis*. The predominant mites of allergic importance in South Africa[1,4] and most parts of the world[5–7] are from the genera *Dermatophagoides* (*D pteronyssinus* and *D farinae*),[8] making up 60–90% of HDM globally.[9] Dustmite allergen particles are very tiny (~15–30 microns in diameter) and can become airborne for short periods during walking and cleaning activities (generally within 20 minutes);[10] this leads to exposure via inhalation, ingestion or cutaneous routes.[1,6] In Africa, high sensitisation to *D pteronyssinus* (46%) and *D farinae* (44%) was reported among allergic rhinitis (AR) patients in Bloemfontein, South Africa.[1] In Zimbabwe, sensitisation to both mites was shown in two-thirds of patients attending an allergy clinic.[11] However, in Germany, *D farinae* 1 (which was predominant) and *D pteronyssinus* 1 plus *D farinae* 1 (>10 μg/g of mattress dust), respectively, posed an increased risk of wheeze and breathlessness (odds ratio (OR) = 4.04, 95% confidence interval (CI): 1.53–10.64 and OR = 2.78, 95% CI: 1.06–7.28).[6]

D farinae and *D pteronyssinus* replicate and thrive at a favourable percentage relative humidity of 50% and 60% respectively.[7] These mites proliferate in humid[12] and warm environments, including hot and dry climates such as that in South Africa.[13] However, their prevalence declines in dry and cold winters[13–15] and in higher-altitude cities compared to those at the coast.[1] Viljoen et al found *D pteronyssinus* to be the most common mite in hospitals in three South African coastal cities (Port Elizabeth), Durban, Cape Town). High counts of mites were associated with the subtropical east coast in KwaZulu-Natal rather than the highveld of Gauteng, where the relative humidity is lower.[13] Durban's provincial hospitals had higher mite densities and infestations compared to private hospitals in

TABLE I: HOUSE-DUST MITE SPECIES REPORTED IN VARIOUS OCCUPATIONAL SETTINGS

HOUSE-DUST MITE SPECIES	OCCUPATIONAL SETTINGS
D farinae	Archives,[1] buses,[25] fishing boats,[16] hospitals,[4,5,18] hotels,[6,7] institutes and libraries,[18] offices,[1,2,3,21] poultry farms,[9] schools,[8,20] submarine,[17] taxis,[25] textile recycling industry,[8] trains[24]
D pteronyssinus	Archives,[1] aeroplanes,[6,10] buses,[22,25] churches,[10] cinemas,[6,10,12] fishing boats,[16] hospitals,[4,5,10,18] hotels,[10,7] institutes and libraries,[18] offices,[1,2,3,10,11,21] poultry farms,[9,13] schools,[4,8,20] submarine,[17] taxis,[25] apartments,[14] trains[22,23,24]
Euroglyphus mayneia[α]	Homes,[15] hospitals, libraries and institutes[18]

[α]HDM commonly associated with recombinant allergens D pteronyssinus (Der p 1) and D farinae (Der f 1) group 1 allergens.

late summer, possibly due to better hygiene practices in private hospitals.[4] Whereas *B tropicalis* sensitisation has been reported in South Africa, it is not the predominant mite species: 52% of patients were sensitised to the mite in northern KwaZulu-Natal in the study by Jeevarathnum et al.[1,16,17] These findings raise the question of the role of HDM as an occupational risk for developing work-related allergies.

CLINICALLY RELEVANT ALLERGENIC MOLECULES

Several clinically relevant HDM allergens have been identified in various workplaces (see Table I), inevitably posing a risk of exposure among workers. The faecal particles of mites consist of an amorphous mass of partially digested skin scales and other food materials, which are enclosed by a chitinous peritrophic membrane. These particles are then aerosolised.[18] The associated constituents have a biological and immunological significance which contributes to the particles' inflammatory response and allergenicity.[18]

OCCUPATIONAL RISK CATEGORIES FOR HDM EXPOSURE

An occupational risk classification has been proposed for dust exposure to mites as low (mite allergen levels up to 2 µg/g of dust), moderate (between 2 µg/g and 10 µg/g) and high (exposure >10 µg/g).[8] A concentration of greater than 10 µg/g of dust containing *Pyroglyphidae* allergens (*Der p* 1 and *Der f* 1) is proposed as the risk threshold to elicit severe symptoms or asthma and 2 µg/g (~100 mites per gram of dust)) is proposed as the risk threshold for sensitisation in human beings.[19] However, these criteria should not be regarded as more than a guide. The risk levels for airborne exposure may be lower, even though they have not been described.[20] This is supported by an investigation which showed an association between work-related respiratory tract symptoms and skin-test reactions among 17% of office workers at levels above 1 µg/g floor dust.[21] Therefore, workers in different workplaces may be at varying degrees of risk depending on the levels of HDM exposure and an individual's immune status. Risk classification also depends on several other factors relevant to the indoor mite population: climate, building characteristics, relative humidity and cleaning schedule.[19]

HEALTH EFFECTS

The inhalation of HDM allergens elicits an IgE inflammatory response of the nose and lungs, resulting in respiratory symptoms, rhinitis and asthma in sensitised people.[13,15,16,20,22–25] A more recently described mite allergen is *Der p* 23, a peritrophin-like protein found in the peritrophic lining of the gut and in faecal particles, which appears to be a major allergen associated with asthma.[26] Although anaphylactic shock is rare, a fatal anaphylaxis case after exposure to high levels of *D pteronyssinus* and *D farinae* in an individual with a history of HDM allergy has been reported.[27] This indicates that HDM allergy can be severe in a few individuals, which is further evidence of the need to reduce environmental exposure through monitoring, which will also help with clinical management.[25] Furthermore, *Der p* 1 and *Der f* 1 have also been recognised as causative agents in the development of atopic dermatitis (AD).[25] A previous study showed that IgE antibodies to *Der p* 11 were more common in patients with AD, which implies that eczematous skin allows allergens to penetrate the skin easily, even those with molecular weights as high as 100 000 Da.[11]

OCCUPATIONAL EXPOSURE TO HOUSE-DUST MITE ALLERGENS

Exposure to HDM allergens has been reported both in the home and in public and occupational settings;[28] however, views on their role as causative agents of work-related allergies and asthma have been controversial. Table I lists the various workplaces in which HDM allergens were reported.[8] The list was compiled in a study which investigated Pyroglyphid as a source of work-related allergens and reported their presence in military barracks, taxis and animal facilities (eg those for poultry and pigs, zoos and laboratories).[8] In addition, 33.9% of atopy among South African poultry workers was found to be driven by sensitisation to HDM (*D pteronyssimus* 24.8% and *D farinae* 23.5%),[28] although the cause of HDM as an occupational allergen was not shown. Nonetheless, atopy to HDM may predispose workers to developing other allergies in the workplace.[29] *D pteronyssinus* and *D farinae* were the most frequent allergens contributing to sensitisation among students in settings in sub-Saharan Africa, the former being the dominant species.[30] Studies investigating, among others, HDM allergens found respiratory symptoms to be common among office workers.[19,31,32] Common work environments where HDMs are isolated include those containing upholstered furniture, soft furnishings, textiles, bedding material, floors and carpets, with people being the main vectors of transmission through clothing.[4,9,13,19,33]

DIAGNOSIS OF HDM SENSITISATION

The diagnosis of HDM sensitisation can be complex, especially

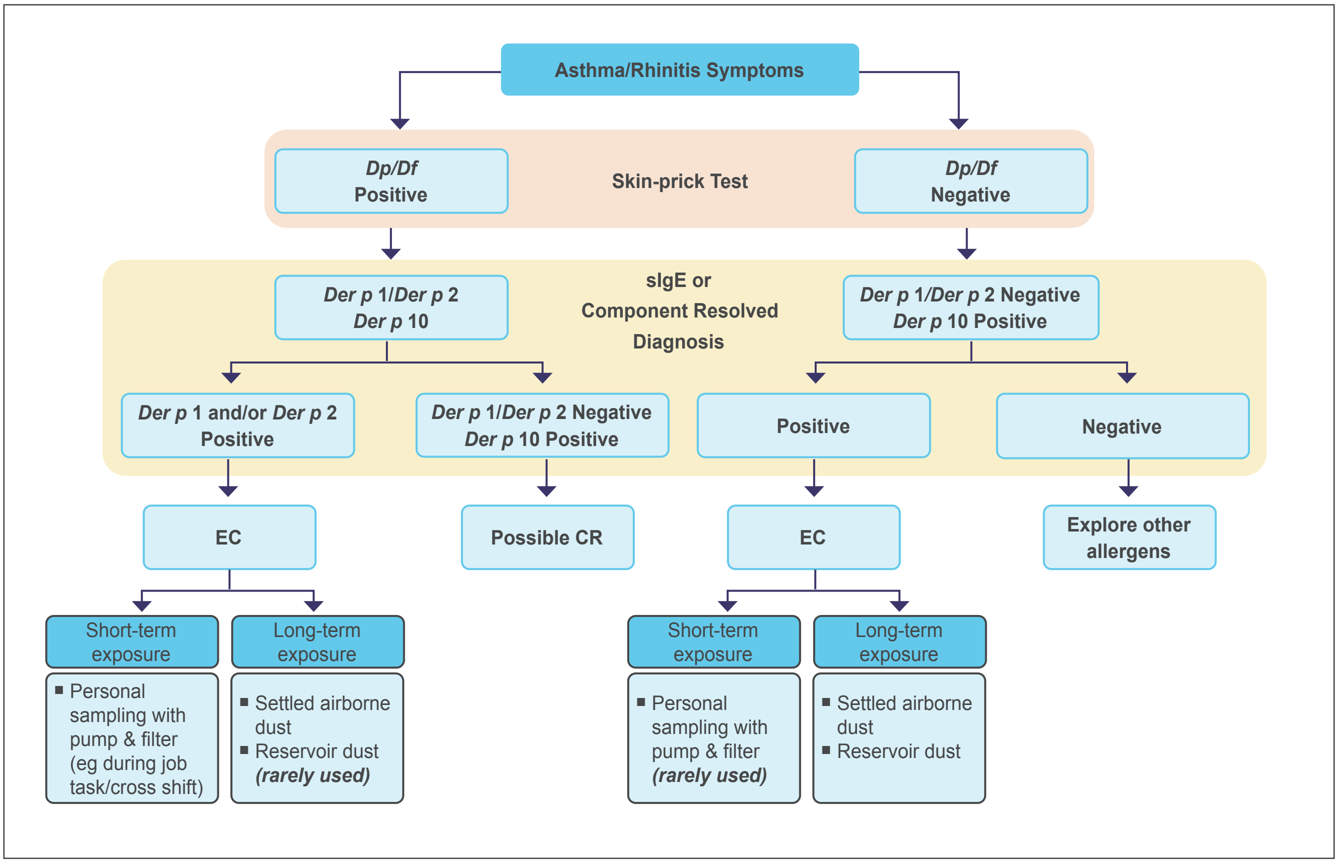

Figure 1: An adapted algorithm that could be applied to diagnosing HDM allergy in the workplace[20,25]
Dp – *D pteronyssinus,* Df – *D farinae, CR – cross-reactivity, EC – environmental control.*

in polysensitised individuals. Misclassification results in false positive rates; therefore, a doctor's diagnosis of AR coupled with an accurate occupational and medical history, medical examinations and a skin-prick test (SPT) can be valuable (see Figure 1). Testing mite allergy should be considered a routine diagnostic procedure in occupational settings where dust mites are occupational hazards.[12,34,35] Skin-prick testing is the primary means of diagnosis, and dustmite extracts are included in all inhalant panels. While a wheal of 3 mm and greater attributable to one HDM is considered positive, it is common practice to test with both *D pteronyssinus* and *D farinae*. This is recommended because, even though a particular mite may be dominant in a geographic area, the results of testing for the two HDMs provide more convincing positive or negative results. It is also compelling because *D pteronyssinus* extracts often show great variability in allergen composition.[36] In addition, testing with *B tropicalis* may be beneficial in tropical areas. In-vitro testing for a specific IgE can be conducted using extracts of *D pteronyssinus (Der p), D farinae (Der f)* and *B tropicalis (Blo t)*. Some evidence suggests that the size of the SPT wheal or of the IgE titre is a useful predictor of the risk of allergic disease.[35]

The criteria for judging sensitisation are well defined; however, the criteria for adjudicating the role of HDMs in occupational cases are less robust. Therefore, consider the following:

a. The worker should be allergic only to HDM.
b. The SPT or IgE test for HDM should dominate other perennial allergens.
c. A measurement of HDM allergens in dust sourced from the workplace can be very useful.
d. It is advantageous to know the average levels of HDM allergens in the geographic area or the dwellings where the worker resides.
e. Testing with species-specific components may be warranted where co-exposure exists or is suspected, as high cross-reactivity has been shown between *D pteronyssinus* and *D farinae* but is low between *Dermatophagoides* and *B tropicalis*. Figure 2 shows the clinically relevant allergens with known cross-reactivity for *B tropicalis* and *D pteronyssinus*. Component-resolved diagnosis may be useful in situations where genuine sensitisation is unclear and has to be defined.[20]

Consideration of the cross-reactivity and co-sensitisation of mites should be prioritised for some workers with multiple mite exposure – for example, in the milling industry, where dust mites and storage mites are prevalent. Co-sensitisation to storage mites is common in people sensitised to *D pteronyssinus*.[34] Moderate cross-reactivity was found between *Dermatophagoides* species and other HDMs, such as *Euroglyphus maynei*.[37] However, immunological cross-reactivity is low between Pyroglyphidae (HDM) and non-*Pyroglyphidae* mites (storage mites).[34]

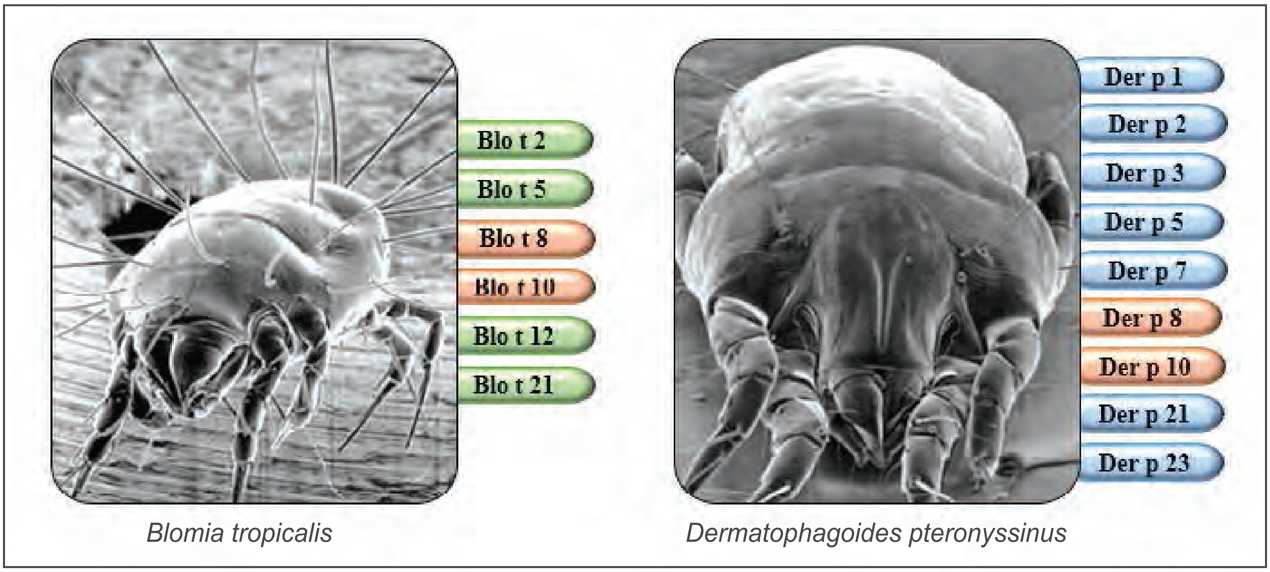

Figure 2: Clinically relevant allergens from B tropicalis *and* D pteronyssinus*. Allergens shown to have cross-reactivity are highlighted in orange (Adapted from EAACI molecular allergology user's guide*[20]*) Mite photo source <https://www.inmunotek.com/en/allergy/allergenic-mites/>.*

MONITORING HDM ALLERGEN EXPOSURE IN THE WORKPLACE

Routine monitoring of aeroallergen exposure based on the measurement of airborne concentrations (ng/m^3 or pg/m^3) is important in managing allergic respiratory diseases and identifying inadequate controls.[7] Although there is no absolute standard to compare the results to, repeated measurements can provide useful information on exposure levels, including when major changes are made (eg changes to cleaning procedures).[25] Since human exposure occurs mainly through inhalation, bulk dust measurements are a poor surrogate of HDM exposure compared to air sampling.[7]

Sensitive and specific enzyme immunoassays (EIA) to detect single airborne mite allergens (*Der p* 1 and *Der f* 1) to assess occupational environments are available commercially to quantify individual allergens[25] and should be used to monitor exposure to settled dust and air.[6] A comparison of inhalable airborne samples using a dustmite EIA showed significantly higher dustmite antigens (*Der f* 1) from textile recycling, bed-feather filling, feed production, grain storage and cattle stables than in living areas. In addition, 62% of floor dust and 6.5% of airborne samples contained *Der f* 1; 33% floor dust and 1.1% airborne samples contained *Der p* 1.[7] Similarly, in a Polish study, *Der p* 1 levels were detected in 54% of workplaces and *Der f* 1 in 55% of workplaces, with the highest levels found in samples from upholstered seats for both allergens. Furthermore, one sample of *Der p* 1 and *Der f* 1 exceeded the proposed threshold in eliciting symptoms by twofold (19.5 ug/g) and sevenfold (77.5 ug/g), respectively.[19] Measuring HDM is beneficial where there is specific evidence of the effects of reducing exposure for *Der p* 1 (from 13 µg/g to 0.2 µg/g) and symptom relief among mite-allergic individuals.[39] Risk-based environmental HDM air monitoring and quantification in settled or reservoir dust samples provide estimates of workplace exposure levels.[7] In addition, since air disturbances in the workplace are known to produce highly inhalable airborne allergens, agitation should be avoided and best practices, such as rigorous cleaning, must be followed.[7,19]

MANAGEMENT OF WORKERS WITH HDM ALLERGY

Risk assessments should include establishing the degree of exposure and evaluating the effectiveness of the existing allergen control measures. The management of workers with HDM allergies consists of testing, treatment, education, avoidance and proper protection. Avoidance may be coupled to a written plan on environmental controls, although avoidance may be challenging, given the ubiquity of HDM in domestic and workplace settings – especially since the mites are invisible to human beings.[20] The management of affected workers or patients can, however, focus primarily on allergen avoidance without having to conduct allergen measurement if combined evidence of a definite diagnosis is sufficient.[25] Allergen avoidance measures such as limiting or replacing soft furnishings, adequate ventilation (6–12 ACH) and reducing the level of humidity (~30%) are capable of reducing dustmite concentrations to low antigen levels.[39–42] The use of non-upholstered furnishings as a preventive measure was demonstrated in one study: very low to zero mite allergen levels were isolated in the office and laboratory surfaces.[41,42] However, if upholstered chairs are used, increased vacuum cleaning is recommended, particularly in office environments.[19] In some instances, introducing engineering controls (eg local exhaust ventilation) to reduce the sources of allergens is the most effective measure for alleviating work-related symptoms and chronic conditions.[25,42] The engineering controls may be supported by HDM environmental measurements to evaluate whether controls are working.[20] Education should include the role HDM allergens play in both acute and chronic symptoms.[20]

AIM OF STUDY

This study aimed to determine the proportion of HDM sensitisation among workers in various industries and to highlight the role of HDM exposure and current developments in occupational settings.

TABLE II: DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS			
VARIABLE	NUMBER (*n*)	PERCENTAGE (%)	PEARSON χ^2, P-VALUE
Age group			$\chi^2 = 5.739$, $p = 0.125$
18–25	41	4.85	
26–39	318	37.59	
40+	454	53.66	
Not reported	33	3.90	
Gender			$\chi^2 = 1.205$, $p = 0.547$
Male	566	66.90	
Female	273	32.27	
Not reported	7	0.83	
Atopy			$\chi^2 = 169.393$, $p \leq 0.000$
Yes	257	30.38	
No	589	69.62	

METHOD

STUDY POPULATION

In this retrospective study, conducted between January 2002 and April 2022, the sensitisation profiles of 846 workers (≥18 years old) were tested with HDM allergens and other common aeroallergens. Consent was sought from the patients prior to testing. Ethical clearance was obtained from the University of the Witwatersrand's Human Research Ethics Committee (Medical) (M200598).

DATA COLLECTION

The Occupational Allergy (OA) clinic at the National Institute for Occupational Health (NIOH) of the National Health Laboratory Service (NHLS) in Johannesburg, South Africa, tests workers from various South African industries for occupational allergies when they present with suspected respiratory allergies. All the patients were seen by occupational medicine specialists, who conducted interviews and collected their clinical and work histories. The information was extracted from the SPT database managed using Excel 2016 (Microsoft, Washington, DC, United States). Their demographic and occupational information was collected. Mono-sensitisation to HDM and atopy status were estimated across industries. The workers' sensitisation to *D pteronyssinus* and *D farinae* was compared to determine any associations.

SKIN-PRICK TESTS

The SPTs involved placing a drop of the allergen solution on the skin of the forearm and then pricking the skin through the drop using a sterile lancet. After 15 minutes, the reactions were assessed by the size of the wheal produced. A positive result was indicated by a mean wheal diameter measuring 3 mm or more. Atopy was defined as a positive SPT to three or more aeroallergens.

TABLE III: PREVALENCE OF SENSITISATION TO COMMON AEROALLERGENS IN WORKERS TESTED AT THE NIOH, 2002–2022			
COMMON INHALANTS	*n*	POSITIVE	% POSITIVE
D farinae	24	10	42
D pteronyssinus	834	282	34
Cockroach group mix	762	199	26
Bermuda grass	820	201	25
Tree mix	415	88	21
Corn pollen	818	173	21
London plane tree	411	75	18
5 grass group	820	145	18
Dog	828	134	16
Cat	822	133	16
Mould mix	537	65	12
Chicken feathers	406	31	8
Feather mix (chicken, duck, goose)	412	26	6
Aspergillus spp	261	16	6

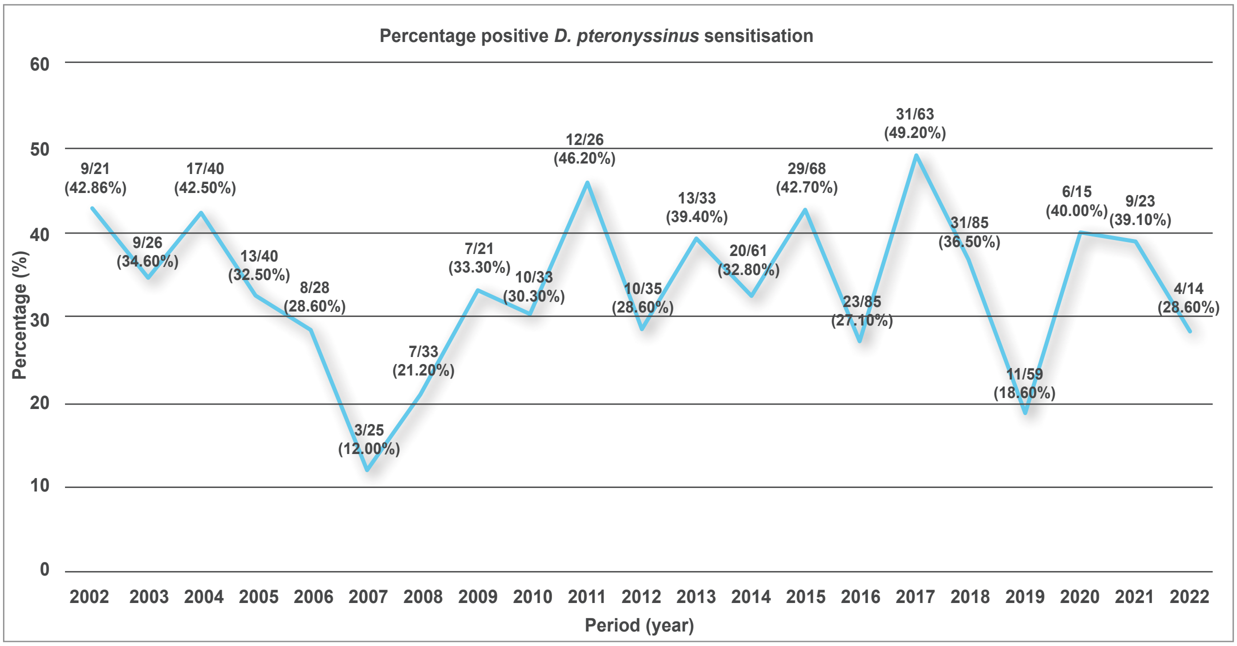

Figure 3: Sensitisation pattern to D pteronyssinus *in workers tested at the NIOH between 2002 and 2022*

STATISTICAL ANALYSIS

Descriptive analysis was performed using STATA version 16 (Stata Corp® College Station, Texas, United States) and it included the frequencies and percentages of categorical variables. Means, medians and ranges were used for continuous data. The percentage positivity of sensitisation to *D pteronyssinus* and *D farinae* tested at the NIOH in workers was calculated and compared to various occupational settings and the general public. The relationships between age group, gender, atopy and the presence of HDM sensitisation were tested using chi-squared tests. Spearman correlation coefficients were used to determine the relationships between the mite allergens.

RESULTS

The mean age of the workers was 42.0 ± 10.7, with more than half of them (53.66%) older than 40 years; however, there were no significant differences between *D pteronyssinus* sensitisation in the different age groups (χ^2 = 5.7386, p = 0.125), nor were there between the genders of the workers (χ^2 = 1.2052, p = 0.547), although more male workers (66.90%) than female workers were tested (see Table II). More atopic workers (65.76%) were sensitised to *D pteronyssinus* compared to non-atopic individuals (19.58%) (χ^2 = 169.3928, $p \leq 0.000$).

COMMON AEROALLERGENS

Of the 8 170 common aeroallergen tests (14 allergens) performed on the 846 workers, *D farinae* (42%) and *D pteronyssinus* (33%) had the highest proportion of positive test results, followed by cockroach mix (25%) (see Table III). The *D pteronyssinus* allergen was tested for between January 2002 and April 2022; however, only 24 patients were tested for *D farinae* sensitisation during the period 2002–2005.

SENSITISATION TRENDS FOR HDM

Figure 3 shows the pattern of sensitisation to *D pteronyssinus* from 2002 to 2022. There was no specific trend; however, the lowest percentage of sensitisation was registered in 2007, at 12.0%, and the highest was in 2017, at 49.2%. This declined by 2022 to 28.6%.

HDM SENSITIVITY BY TYPE OF INDUSTRY

Information about the company, job description and/or exposures was available for 229 of the 282 HDM-positive workers: it was used for sector classification (see Table IV).

The sector that had the highest number of HDM positivity was the manufacturing category (119, 52%), followed by the mining and quarrying sector (39, 17%). The manufacturing sector includes a broad range of different industries, including the manufacture of textiles, pulp and paper, rubber and plastic, and metal products; the beverage sector; refined petroleum and chemical production; electrical machinery and apparatus, and food products and beverages. The majority (39/44) of workers in the manufacturing of food products and beverages category were in the bakery and flour-production industries and only one patient per category was observed in these manufacturing industries: edible oils and fats, food flavourants and fragrance agents, pastas and spices (see Table IV). In the study sample, the metal products manufacturing industry had a total of 45 workers, 28 of them working in different types of metal industry and 17 in metal-refineries.

Almost half of the workers (18/39) in the mining and quarrying category sensitised to HDM were from the platinum mines, followed by gold (7), chrome (6), coal (4), diamond (2) and copper (1).

In the human health and social work category, all the workers were from the human health industry and none from social activities. The majority (12) in the human health industry who

TABLE IV: HEAT MAP SHOWING HDM MONO-SENSITISATION AND ATOPY STATUS ACROSS INDUSTRIES

INDUSTRY CLASSIFICATION	JOB DESCRIPTION	MONO-HDM	ATOPY	TOTAL
Agriculture & Forestry		**1, 20%**	**2, 40%**	**5**
Chicken farm	General worker	0, 0%	0, 0%	1
City Park	Mowing the lawn (city park)	0, 0%	1, 100%	1
Vegetable farm	2 mushroom farm (1 picker, 1 packer) 1 vegetable farm general worker	1, 33%	1, 33%	3
Electricity, gas, steam & air conditioning supply		**1, 17%**	**4, 67%**	**6**
Electricity generation	1 boilermaker, 1 mechanical technician	0, 0%	3, 100%	3
Gas manufacturer	2 machine operators, 1 technical assistant	1, 33%	1, 33%	3
Human health & social work activities		**2, 11%**	**12, 67%**	**18**
Blood transfusion	Donor attendant	0, 0%	1, 100%	1
Department of Health	Assistant director	0, 0%	0, 0%	1
Fire station	Firefighter	0, 0%	1, 100%	1
Hospital	8 nurses, 4 cleaners	2, 17%	7, 58%	12
Medical laboratory	laboratory personnel technicians, technologist,	0, 0%	3, 10%	3
Manufacturing		**29, 26%**	**63, 53%**	**119**
Metal products		13,29%	21,47%	45
– Metal products including motor vehicles, machinery & equipment	Spray painters, plating specialist, fitter & tuner, machine operator, general workers, welder, diesel mechanic, boilermaker, mechanic, shutter hand, engineer, security guard	8, 29%	15,54%	28
– Metal refinery industries		5, 29%	6,35%	17
• Base metal refinery	Sample processor	0, 0%	1, 100%	1
• Chrome refinery	Furnace operator – chrome	0, 0%	3, 75%	4
• Precious metals refinery	6 security guards, machine operator, metal processor, process controller, processor operator	4, 36%	2, 18%	11
• Vanadium-processing plant	Furnace attendant	1, 100%	0, 0%	1
Chemicals products		6, 35%	9, 53%	17
– Chemicals & chemical products	Machine operator, pharmacist, carbide grinder, colour matcher – paint manufacturer, general worker	3, 30%	6, 60%	10
– Coke, refined petroleum & nuclear fuel	Welder, grinder operator, machine operator, engineer, general worker	3, 43%	3, 47%	7
Electrical machinery & apparatus	Electric cable manufacturer, mechanical assembler – electronics manufacturing	0, 0%	2, 100%	2
Rubber & plastic production	Foam plant manager, processor –manufacture of plastic, machine operator	1, 33%	2, 67%	3
Textiles	Seamstress, operator of rope manufacturing machine	0, 0%	2, 100%	2
Pulp, paper, & paper products	Engineer, wash bay attendant, dry end operator	2, 50%	2, 50%	4
Wood & wood products	Woodcutter operator, furniture repairer	1, 50%	1, 50%	2
Food products and beverages		6,14%	24, 55%	44
– Bakeries ingredients	Dispatch, forklift driver and store clerk, training miller	1, 25%	3, 75%	4
– Bakery	Baker	2, 6%	19, 61%	31
– Exposed to flours, industry not specified	Exposed to flours, job not specified	0, 0%	1, 25%	4
– Brewery	Cleaner	1, 100%	0, 0%	1
– Edible oils & fats	Site foreman – edible oils production	0, 0%	0, 0%	1
– Pasta manufacturer	Regrinding of rejected pasta	0, 0%	1, 100%	1
– Spice	Exposed to spices, job not specified	1, 100%	0, 0%	1
– Food flavouring and fragrances agents	Manufacturing of chemicals to make food flavouring and fragrances	1, 100%	0, 0%	1

TABLE IV: CONTINUED

INDUSTRY CLASSIFICATION	JOB DESCRIPTION	MONO-HDM	ATOPY	TOTAL
Mining and quarrying		**4, 10%**	**30, 77%**	**39**
Chrome mine	2 machine operatosr, rock breaker, ventilation installer, boilermaker	0, 0%	4, 67%	6
Coal mine	Machine operator, mining operator, lampman	1, 25%	3, 75%	4
Copper mine	Lab operator	0, 0%	1, 100%	1
Diamond mine	Load haul dump operator, artisan	0, 0%	2, 100%	2
Gold mine	2 diesel mechanics, stopping labour, underground supervisor, production assistant, miner underground	2, 29%	5, 71%	7
Mining – type unspecified		0, 0%	1, 100%	1
Platinum mining	3 belt attendants, winch operator, equipping helper, stock issuer & receiver, rock crusher, drilling operator, emulsion attendant, laboratory chemist, underground assistant	1, 6%	14, 78%	18
Transport		**4, 27%**	**6, 40%**	**15**
Rail transport	Tele control, electrician	2, 100%	0, 0%	2
Road transportation	Electrician – bus service, 5 drivers (1 medical lab, 2 waste truck, 2 fuel truck	2, 33%	2, 33%	6
Air	3 aircraft technicians, 2 aircraft mechanics, 2 aircraft fitters	0, 0%	4, 57%	7
Construction		**0, 0%**	**5, 72%**	**7**
Roads and earth works, Construction and maintenance	Welder, mechanics area manager, spray truck assistant, operator	0, 0%	2, 50%	4
Cement, lime & plaster manufacturer	Brick clapper preparation, machine operator	0, 0%	3, 100%	3
Other		**3, 15%**	**13, 65%**	**20**
Education	Music teacher, metallurgical doing training and simulation for mines	0, 0%	2, 100%	2
Finance and insurance	Group financial manager	0, 0%	1, 100%	1
Hotel and restaurants	Child caregiver at a casino	1, 100%	0, 0%	1
Household	Domestic worker	0, 0%	1, 100%	1
Information and communication	IT manager	0, 0%	1, 100%	1
Research and experimental development on natural sciences and engineering	Medical lab technician process operator at a mining research lab	0, 0%	2, 100%	2
Cleaner industry not specified	Cleaner	0, 0%	1, 100%	1
Waste management	Skip operator, artisan	0, 0%	1, 50%	2
Wholesale and retail	Deli serve assistant, clothing salesperson, butchery service assistant, stock room assistant	1, 20%	2, 40%	5
Jewellery & precious metals	Jewellery repairer & polisher	0, 0%	1, 100%	1
Exposed to platinum dust, but the company not specified	Job not specified	1, 33%	1, 33%	3

Key: Colour scale showing atopy status by industry and occupation. The colour conditioning ranges from green indicating no atopic workers to red the highest number of atopic workers. Colour range 0 – 61

were HDM SPT-positive were hospital workers, eight of them nurses and four cleaners. There were only three laboratory workers who were HDM SPT-positive.

The agriculture and forestry group had five HDM-positive workers, whereas the electricity, gas and steam industry had six. The transport category included workers from the road, rail and air sectors, with rail and road dominating HDM sensitivity (see Table IV). Of the HDM SPT-positive workers, 44 (19%) were monosensitised for HDM and 135 (59%) were classified as atopic, that is, positive to three or more other common inhalants. Atopic workers ranged from 40% in workers from the agriculture, forestry and transport industries to 77% in the mining and quarrying category (see Table IV).

The results of the 24 workers tested with both *D pteronyssinus* and *D farinae* are shown in Table V; they were different in only 25% of the workers tested. The Spearman correlation coefficient

TABLE V: ASSOCIATION RESULTS OF WORKERS TESTED WITH *D PTERONYSSINUS* AND D *FARINAE*

DESCRIPTION	NO. POSITIVE, % POSITIVE
Negative for both *Dp* and *Df*	10, 41.7%
Positive for one HDM only	6 [4 *Dp*, 2 *Df*], 25.0%
Positive for both *Dp* and *Df* 2	8, 33.3%

($r = 0.5071$, $p = 0.0114$) shows a moderate correlation between the two mites, and this may be the result of cross-reacting allergens.

DISCUSSION

The percentage sensitisation to *D farinae* (41.67%) and *D pteronyssinus* (33.81%) among workers referred to the NIOH OA clinic were comparable to the results of a German study, where *D farinae* was predominant in floor and airborne dust samples at workplaces.[7] Similarly, these two HDMs were the most frequent allergens contributing to sensitisation among students in a sub-Saharan Africa setting, with *D pteronyssinu*s being more dominant than *D farinae*.[30] In contrast, a study conducted among poultry workers tested at the NIOH using the Immunocap test method showed a similar percentage sensitisation for *D pteronyssimus* (24.8%) and *D farinae* (23.5%).

Since HDMs are ubiquitous, it is important to establish whether the HDM sensitisation is occupationally acquired for implementing appropriate preventive measures and as evidence for workers' compensation claims. In this study, we aimed to use routinely collected data to investigate the association between HDM sensitisation and the type of job performed across various industries. All the testing for HDM was requested as part of the ten common allergens to determine atopy and not because it was a suspected workplace allergen.

Although the current findings for *D farinae* (41.7%) and *D pteronyssinus* (33.81%) were contrary to those of Viljoen et al, who showed *D pteronyssinus* to have a higher incidence,[4] the results still confirm a fairly high prevalence of sensitisation to HDM in the *Dermatophygoides* genus. Furthermore, fewer patients were tested for both species in the current study. Our results concur with a study of AR patients in Bloemfontein, in which 46% of the patients sensitised to *D pteronyssinus* and 44% to *D farinae*,[1] although the findings were higher for some occupational settings. The difference may be attributed to the geographic localities, because certain genera of HDM tend to be dominant in certain areas. High counts of mites were also associated with the subtropical east coast in KwaZulu-Natal rather than the highveld of Gauteng, where the relative humidity is lower.[33] Durban provincial hospitals had higher mite densities and infestations than private hospitals,[4] suggesting that healthcare workers in coastal public hospitals are at much higher risk of exposure than their private counterparts. This may be due to different work practices.

The prevalence of Immunocap positivity was higher (56%) for *D pteronyssinus* in non-occupational cases tested at a private laboratory in South Africa;[44] however, this may be due to selection bias because only Phadiatop (UNICAP)-positive patients were included in the analysis. The positivity rate by province ranged from 38% to 58%, which affirmed geolocation variability. Furthermore, a Zimbabwean study also demonstrated sensitisation to both *D farinae* and *D pteronyssinus* in two-thirds of patients attending an allergy clinic.[42] Based on these results, it could be argued that the prevalence in the current study mirrors that of the general population, as shown in the Bloemfontein and Zimbabwean studies.

This similarity poses a challenge to establishing an occupational link. In the majority of the cases reported, people are sensitised to dust mites at home and may have developed related allergic diseases in childhood or adolescence;[8] however, their condition may be aggravated by HDM exposure in the workplace.[7] In temperate climates, residential exposure to HDM is by far more common than occupational exposure; but workplaces with moderate and high exposures to HDMs may contribute to the development of work-related sensitisation and allergic disease. In such cases, when measuring the exposure to HDM particles both at home and at work, it is important to establish both the source and the level of exposure.[8] The probable association between domestic and workplace exposure and work-related symptoms was not explored in the current retrospective study because the data were limited and HDM was not the primary allergen under investigation.

Information on whether the workers' symptoms improve when they are away from work can help to shed light on whether the source of sensitisation is occupational or otherwise; however, this information was also not available, which has an impact on the proper management of presumably exposed workers. Occupational health specialists should have a high index of suspicion when assessing workers with workplace exposure to HDM and whether they are sensitised to HDM to avoid the development or aggravation of allergies. Home or public exposure should be considered, especially when temperate climates are conducive to HDM growth.

The possibility of HDM sensitisation being related to the workplace is plausible, given that 19% of the patients who reported work-related symptoms tested positive to HDM only. In addition, several industries or occupations have previously been identified as high-risk workplaces for HDM exposure and the source of HDM sensitisation to workers, as previously mentioned. Accordingly, workers in offices, healthcare facilities (including homecare), hotels, textile factories and the upholstery industry may be exposed to HDM. Therefore, mitigation strategies (eg robust hygiene practices, acaricide treatment and/or exposure to natural sunlight) should be guided by a risk assessment.[4,13,19,33,45] Furthermore, industries such as the textile industry, which the cases represent, are likely to contain fittings and furnishings conducive to HDM growth.

The percentage of workers sensitised to HDMs at the NIOH clinic was not different from that of non-occupational cases diagnosed with AR from 1 November 2013 to 31 October 2019 at a private ear, nose and throat (ENT) practice in the Northern Cape. There, sensitisation to the mite mix (consisting of *D farinae* and *D pteronyssinus*) was 37% using the SPT method and 38% for *D pteronyssinus* using the Immunocap tests.[46]

The true prevalence of HDM allergy as a consequence of workplace exposure is unknown in South Africa, primarily because it is considered an aeroallergen and the association with work or workplaces is rarely considered. In the light of this, data from occupational allergy clinics such as the NIOH may represent an overestimation because workers with respiratory allergy problems are seen at these centres, even though the prevalence is similar to that found in other studies where HDM exposure in work settings was investigated. On the contrary, there is a strong likelihood of under-reporting of HDM allergy among workers who may not be aware of the risks of exposure in workplaces, as the label 'house-dust mite' or 'HDM', based on its origins, may be confusing.

Although South Africa lacks a robust system of occupational allergy surveillance, this article highlights the value of using fledgling routine data in unmasking the role of ubiquitous allergens in the workplace. HDMs are often overlooked as they are considered common aeroallergens. This is important because allergic and asthmatic conditions may become chronic if they are not well managed. As mentioned above, whether occupationally acquired or work-aggravated, respiratory symptoms, rhinitis and asthma can be debilitating and this has economic implications due to absenteeism, poor quality of life, long-term performance and low productivity.[47] The analysis also raised concerns regarding industries' misclassification of employment. For instance, a cleaner in a brewery and another in a hospital may use the same cleaning reagents for the floors, but they are exposed to other different materials specific to their industries.

This study also illustrates that more advocacy is needed regarding:

1. occupational allergy to HDM, including *B tropicalis*, if it is geographically relevant to early recognition and reporting by workers;
2. the assessment of any possible association by occupational health practitioners and thorough history-taking;
3. the available testing for HDM (ie SPT, specific IgE, component-resolved diagnosis) to facilitate access to testing, timely diagnosis, surveillance and trend analysis;
4. difficulties with supply chain management because suppliers change species without considering the importance of location and exposure;
5. environmental measurements to demonstrate causality, where relevant;
6. the revision of risk assessment to include HDM as a potential biological hazard.

Given the paucity of information on occupational HDM allergy, particularly in South Africa, large-scale research to investigate exposure–response relationships is warranted to determine the true prevalence of occupational HDM allergy. Assessing the usefulness of the proposed HDM risk categories[28] in managing exposure to HDM should be considered. It is also important to consider individual tolerance levels. Given that a high percentage of workers are sensitised to HDM, especially to *D pteronyssinus* and *D farinae*, it is recommended that protocols be implemented to control HDM exposures in South Africa.

LIMITATION

HDMs were not reported in all the work environments included in this study; it would have been useful to select only those workplaces that have reported HDM allergy. The employment descriptions or work-exposure information of all the workers tested was collected from 2020; therefore, comparisons between sensitised and non-sensitised workers per industry could not be made. This limitation was recognised and included in the database from 2020. Non-occupational cases were only those tested at private laboratories and did not include the general public; therefore it is important to obtain data from public laboratories (eg the National Health Laboratory Service).

It was also not possible to establish whether the workers who tested positive for HDM at the NIOH clinic were sensitised at work, at home or in other public places. This could be established if HDM allergens were to be measured both at home and at workplaces: information on whether the symptoms are worse at work or at home would help to establish where the sensitisation occurred. It is vital to test for HDM allergen concentrations in workplaces of individuals with highly positive HDM SPT results, because such testing can shed light on the causes of exacerbation of symptoms and on the avoidance measures that should be implemented. The NIOH stopped testing for *D farinae* in 2005 because of changes in availability from the supplier; however, based on the criteria for judging sensitisation in occupational settings, workers need only be allergic to HDM – although including two HDMs provides for testing with greater confidence.

CONCLUSION

HDM sensitisation was found to be high among workers presenting for occupational allergy testing at the NIOH, with 19% being sensitised only to HDM and no other suspected allergen. HDMs are major allergens and persistent causes of allergy in South Africa, and have been identified in a range of workplaces. Sensitisation to HDM poses a risk factor in the workplace and for this reason occupational health specialists must examine its contribution to occupational allergies independently of atopy.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

This article has been peer-reviewed.

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