WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Impact of House Dust Mites on Human Health: Allergic Reactions and Asthma

Mr.Hardik Rakshe[1], Miss.Vaibhavi Ghundare[2], Dr.Hemalata Dange[3], Dr.Pramod Ingale[4], Dr.Vikas Shende[5], Miss.Sanchita Dhumal[6], Dr.Vijay Warad[7],

[1]B.Pharm Student ,Dnyanvilas College Of Pharmacy, Pune,Maharashtra,India

[2] B.Pharm Student ,Dnyanvilas College Of Pharmacy, Pune,Maharashtra,India.

[3]Assistant Lecturer, Department of Pharmacology, Dnyanvilas College Of Pharmacy, Pune,Maharashtra,India.

[4]Principal of Dnyanvilas College Of Pharmacy, Pune,Maharashtra,India.

[5]Senior Lecturer, Department of Pharmacology ,Dnyanvilas College Of Pharmacy, Pune,Maharashtra,India.

[6]Assistant Lecturer, Department of Pharmacology, Dnyanvilas College Of Pharmacy, Pune,Maharashtra,India.

[7]MBBS, MD, Clinical Immunology Expert, Pune, Maharashtra, India.

ABSTRACT:

House dust mites (HDMs) are a major source of indoor allergens, contributing to allergic rhinitis, asthma, and other hypersensitivity reactions. The most clinically significant HDM species include Dermatophagoides pteronyssinus, Dermatophagoides farinae, and Euroglyphusmaynei, which thrive in humid environments and produce allergens that trigger immune responses. HDM allergens, particularly Der p 1, Der p 2, and Der p 23, degrade epithelial barriers and activate Th2-driven immune pathways, leading to chronic airway inflammation and increased asthma risk. Early exposure to HDMs significantly contributes to sensitization and disease progression, particularly in children. Diagnostic approaches such as skin prick tests, serum IgE detection, and provocation tests help identify mite-induced allergies. Management strategies include allergen avoidance, pharmacotherapy, and allergen immunotherapy (AIT), with sublingual immunotherapy (SLIT) showing promising long-term benefits. Despite available treatments, allergen exposure remains a challenge, necessitating further research on environmental control measures and targeted immunotherapies. This review highlights the impact of HDMs on human health, their biological and immunological mechanisms, and current treatment approaches to mitigate their effects.

Keywords:House dust mites, allergic rhinitis, asthma, allergen immunotherapy.

Introduction

Domestic mites are a significant source of indoor allergens and are known to cause allergic reactions, particularly in individuals with a genetic predisposition. These mites belong to the subphylum Chelicerata, class Arachnida, subclass Acari, superorder Acariformes, and order Astigmata. The primary species responsible for allergenic reactions are Dermatophagoidespteronyssinus (D. pteronyssinus), Dermatophagoidesfarinae (D. farinae), and Euroglyphusmaynei (E. maynei), all of which belong to the Pyroglyphidae family. Other clinically relevant mites include those from the Glycyphagidae, Acaridae, and Echimypodidae families, often referred to as storage mites. These mites thrive in indoor environments and are known to cause allergic symptoms, including asthma, allergic rhinitis, and eczema, in sensitive individuals.(16)

To produce allergen extracts for clinical purposes, these mites are cultivated under controlled conditions, using precise and optimized culture media. This process ensures that the final product has a suitable allergenic composition, which is essential for diagnosing mite allergies and preparing for allergen immunotherapy. The materials used to prepare these allergen extracts typically come from inactivated mite cultures, which may include fecal pellets, mite bodies, mite parts, egg cases, and skin casts. Initially, mites were cultivated using their natural food source—human skin scales. However, over time, alternative media have been developed, such as animal skin scales, dried daphnia, ox liver, fish food flakes, dog food, rodent chow, wheat germ, and fungal cultures, often supplemented with yeast or vitamins and amino acids.

While there have been various studies on the population growth and development of domestic mites, little research has compared the dynamics of mite populations grown in single versus mixed cultures. Recent studies have investigated and observed the growth patterns of allergenic mite species, including Dermatophagoides, Tyrophagus (family: Acaridae), and Blomia (family: Echimypodidae), during both single- and mixed-population cultivation. This research is important for understanding how different mite species interact and grow under various cultivation conditions, which can further improve allergen extract production and contribute to better diagnostic and therapeutic outcomes for individuals affected by dust mite allergies.

Biology Of House Dust Mites

House dust mites (HDMs) belong to the arachnid subclass Acari and are primarily found in human dwellings, where they thrive in warm, humid environments such as mattresses, carpets, and upholstered furniture. They play a significant role in allergic diseases due to their production of allergenic proteins that trigger IgE-mediated sensitization in humans. The most common HDM species include Dermatophagoidespteronyssinus, Dermatophagoidesfarinae, and Euroglyphusmaynei. These mites are microscopic, typically measuring between 0.1 and 0.4 mm, and lack eyes and

respiratory openings, relying on passive respiration through their thin cuticle. Their anatomy includes specialized structures such as suction cups and pheromone receptors for communication and mating. House dust mites primarily feed on human skin flakes and organic debris, while storage mites, often found in food supplies, prefer protein-rich materials like grains and hay. Mite populations are influenced by environmental factors, with high humidity (75–80%) and temperatures between 20–28°C being optimal for their development. Their life cycle consists of six stages: egg, prelarva, larva, proto- and tritonymph, and adult, with females laying up to 300 eggs during their lifetime. Seasonal variations in humidity affect mite populations, with peaks occurring in late summer and declines in winter. Climate change may further impact their distribution and allergenicity. Understanding the biology of HDMs is crucial for developing effective allergen mitigation strategies and improving the management of mite-induced allergic conditions.(7)

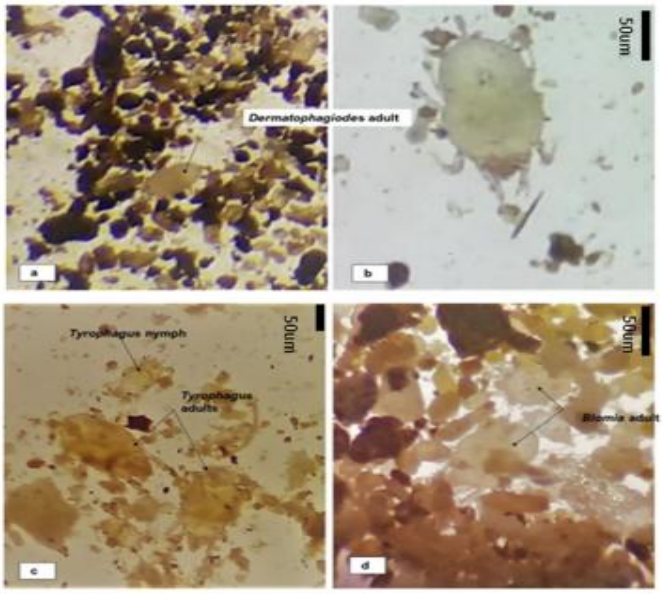

Fig.1 Domestic mites in culture (a,b), Dermatophagoides mites in culture(c), Tyrophagus mites(d), Blomia mites(d)

1.House Dust Mites as an Allergen Source (1)

1.1.Allergenic Components of House Dust Mites

House dust mites (HDM) produce a variety of allergens, but the most clinically significant are *Group 1 (cysteine proteases, Der p 1 & Der f 1), Group 2 (lipid-binding proteins, Der p 2 & Der f 2), and Group 23 (peritrophin-like protein, Der p 23)***. These allergens originate primarily from mite feces, with some present in mite bodies. Studies show that** *Der p 1 and Der p 2 alone account for 50–65% of the total IgE binding***, making them the dominant allergenic proteins.** *Der p 23***, found in the peritrophic membrane of mite fecal particles, was recently identified as another major sensitizer, with** *IgE-binding activity comparable to Der p 1 and Der p 2***. Mid-tier allergens such as** *Der p 4, 5, 7, and 21* **also play a role, binding IgE in about 30–40% of allergic individuals. Minor allergens like** *Der p 10 (tropomyosin) and Der p 20 (arginine kinase)* **contribute to cross-reactivity with other environmental allergens, including seafood and cockroaches.**

1.2.Mechanism of Action of HDM Allergens

Each allergen plays a unique role in sensitization and immune activation. *Der p 1 is a cysteine protease that degrades tight junction proteins in the respiratory epithelium*, weakening the protective barrier and allowing deeper allergen penetration. This enzymatic activity also enhances inflammation by facilitating the release of *pro-inflammatory cytokines like IL-33 and TSLP*, which promote a *Th2-dominant immune response. Der p 2 mimics MD-2, a component of the human TLR4 receptor complex*, allowing it to bind lipopolysaccharides (LPS) and activate innate immune responses, leading to enhanced allergic inflammation. *Der p 23 binds to chitin in mite feces*, stabilizing allergenic particles and increasing their airborne persistence, leading to prolonged exposure and sensitization. Mid-tier allergens like *Der p 7 and Der p 5* are involved in lipid transport and may modulate immune responses through hydrophobic interactions.

1.3.Synergistic Effects in Allergy Progression

The combined action of HDM allergens significantly amplifies allergic responses. *Der p 1 enhances the penetration of Der p 2 and Der p 23*, increasing the allergenic load in the lower airways. The lipid-binding properties of *Der p 2 and Der p 7* act as adjuvants, promoting immune activation and increasing the severity of inflammatory responses. Cross-reactivity further complicates allergic conditions, as individuals sensitized to *Der p 10 (tropomyosin) may also react to shrimp and cockroach allergens*, while scabies infections can lead to increased IgE binding to *Der p 4 and Der p 20*, potentially causing *false-positive allergy diagnoses*. The synergistic effect of these allergens contributes to *chronic airway inflammation, increased bronchial hyperresponsiveness, and a higher risk of developing asthma and atopic dermatitis.*

2.Immunological Mechanisms of Dust Mite-Induced Allergies (2)

2.1.Sensitization Process

House dust mite (HDM) allergens initiate allergic sensitization by penetrating the respiratory epithelial barrier. Their proteolytic enzymes degrade tight junction proteins, increasing epithelial permeability and allowing allergens to reach antigen-presenting cells (APCs) such as dendritic cells (DCs). These APCs process and present HDM antigens to naïve T-helper (Th) cells in the lymph nodes, promoting Th2 cell differentiation. The activated Th2 cells release cytokines like IL-4, IL-5, and IL-13, which drive B cells to undergo class switching and produce allergen-specific IgE. This IgE binds to high-affinity IgE receptors (FcεRI) on mast cells and basophils, sensitizing them for an allergic reaction upon subsequent allergen exposure.

2.2.Response to Re-Exposure

Upon re-exposure to HDM allergens, cross-linking of IgE on sensitized mast cells triggers degranulation, leading to the rapid release of inflammatory mediators such as histamine, leukotrienes, and prostaglandins. This causes an immediate hypersensitivity reaction characterized by bronchoconstriction, increased mucus secretion, and vascular permeability, resulting in airway obstruction, wheezing, and coughing. Additionally, IL-5 recruits eosinophils, which release cytotoxic granules, exacerbating tissue damage and sustaining inflammation. This late-phase immune response prolongs allergic symptoms and contributes to the worsening of airway inflammation.

2.3.Chronic Inflammation and Airway Remodeling

Persistent exposure to HDM allergens leads to chronic inflammation and structural remodeling of the airways, key characteristics of asthma. Continuous Th2-mediated inflammation results in epithelial damage, fibroblast activation, and excessive collagen deposition, leading to airway fibrosis. IL-13 promotes goblet cell hyperplasia, causing excessive mucus production and further airway obstruction. Additionally, prolonged inflammation induces smooth muscle hypertrophy and hyperresponsiveness, increasing airway reactivity and worsening asthma symptoms over time. These structural alterations contribute to irreversible airway changes, emphasizing the long-term impact of HDM allergens on respiratory health.

3.Health Conditions Associated with House Dust Mite Exposure

3.1.1.Allergic Rhinitis (Hay Fever) (3)

Allergic rhinitis is a common allergic disorder affecting approximately ***30% of the population in developed countries***. It is an immune system response to airborne allergens, leading to inflammation of the nasal mucosa. The condition is associated with ***sneezing, nasal congestion, rhinorrhea (runny nose), and itchy eyes, nose, and throat***. Allergic rhinitis can significantly impact an individual's ***quality of life, productivity, and sleep patterns***.

3.1.2.Seasonal vs. Perennial Allergic Rhinitis

Seasonal Allergic Rhinitis: Also known as hay fever, it is triggered by airborne allergens such as *pollen from trees, grasses, and weeds*. Symptoms are more pronounced during specific seasons.
Perennial Allergic Rhinitis: This form persists throughout the year and is commonly caused by *indoor allergens*, including *house dust mites, pet dander, mold spores, and cockroach droppings*.

3.1.3.Impact on Quality of Life and Sleep Disturbances

Allergic rhinitis has a profound effect on daily life, causing *nasal congestion, sleep disturbances, fatigue, and cognitive impairment.* Sleep-related issues include:

- *Worsened nasal congestion at night***, leading to breathing difficulties.**
- **Increased risk of** *obstructive sleep apnea and snoring***.**
- *Daytime fatigue and irritability* **due to poor sleep quality.**

Management strategies focus on allergen avoidance, pharmacotherapy (antihistamines, intranasal corticosteroids), and immunotherapy. Environmental control measures such as *HEPA filters, acaricides, and allergen-proof bedding* have been explored, though their effectiveness varies.

3.2.Asthma (4)

3.2.1.Role of Dust Mite Allergens in Asthma Exacerbation

House dust mite allergens significantly contribute to asthma exacerbation by triggering immune responses that lead to airway inflammation and hyperresponsiveness. Exposure to allergens from common mite species such as ***Dermatophagoides pteronyssinus***, ***Dermatophagoides farinae***, ***Euroglyphusmaynei***, and ***Blomiatropicalis*** can act as a primary cause or risk factor for asthma. These allergens, particularly those in *group 1* (cysteine proteases), increase mucosal permeability and stimulate *IgE-mediated reactions*, worsening asthma symptoms such as wheezing, airway obstruction, and shortness of breath. Studies indicate that up to *78% of asthmatic patients* experience nasal symptoms, highlighting the strong link between HDM allergens and respiratory distress.

3.2.2.AirwayHyperresponsiveness and Chronic Lung Inflammation

Airway hyperresponsiveness and chronic lung inflammation are key consequences of HDM exposure. The allergens activate *T-helper 2 (TH2) cells*, leading to the release of inflammatory cytokines like *IL-4 and IL-5*, which attract eosinophils and mast cells to the airways. This immune response results in excessive mucus production, airway narrowing, and persistent inflammation, making breathing more difficult. Over time, continuous exposure contributes to *airway remodeling*, leading to long-term asthma complications and reduced lung function. Seasonal variations in allergen concentration can further influence asthma severity, with higher mite allergen levels correlating with increased airway hyperresponsiveness.

3.2.3.Children and Asthma Risk Due to Early HDM Exposure

Early exposure to house dust mites significantly increases the risk of asthma in children. Infants and young children living in mite-rich environments, such as those with high dust levels in bedding and carpets, are more likely to develop allergic sensitization. Atopic individuals with a genetic predisposition to allergies tend to produce high levels of *IgE antibodies* in response to HDM allergens, leading to *early-onset asthma*. Studies suggest that childhood allergic rhinitis is a strong predictor of asthma later in life. The *hygiene hypothesis* further proposes that reduced microbial exposure in modern indoor environments increases susceptibility to HDM allergies and asthma.

3.2.4.Wheezing, Shortness of Breath, and Bronchial Obstruction

Common symptoms of HDM-induced asthma include *wheezing, shortness of breath, and bronchial obstruction*, which result from airway inflammation and narrowing. Nocturnal symptoms are prevalent due to allergen accumulation in bedding, leading to nighttime breathing difficulties. Chronic exposure to HDM allergens causes *bronchial constriction and mucus overproduction*, which can worsen asthma severity if not managed properly. Over time, persistent inflammation may lead to structural changes in the airways, making asthma symptoms more severe and persistent.

4.Diagnosis Methods for House Dust Mite Allergy *(5)*

4.1.Skin Prick Test (SPT)

The skin prick test is a widely used method to detect house dust mite sensitization by introducing allergen extracts into the skin and observing allergic reactions. It is highly sensitive, but its accuracy depends on the quality of allergen extracts and patient-specific factors such as medication use. False-negative results may occur due to antihistamine intake, while false positives can arise from urticarial dermographism. Additionally, the presence of allergens such as Der p 23 in test extracts is critical for reliable results.

4.2.In Vitro Testing (Serum IgE Detection)

This method measures allergen-specific IgE antibodies in the blood, helping identify sensitization patterns and diagnose local allergic rhinitis. The detection of major allergens such as Der p 1, Der p 2, Der p 10, and Der p 23 aids in understanding sensitization profiles. Component-resolved diagnostics (CRD) further determine cross-reactivity with allergens like crustaceans and mollusks, improving diagnostic precision. Additionally, specific IgE testing in nasal secretions can help diagnose local allergic rhinitis.

4.3.Provocation Tests

Provocation tests, including nasal, conjunctival, and bronchial provocation tests, are performed to confirm the clinical relevance of sensitization. The *nasal provocation test (NPT)* is considered the gold standard, involving allergen administration in both nostrils and symptom monitoring through peak nasal inspiratory flow (PNIF) or rhinomanometry. The *conjunctival provocation test (CPT)* assesses ocular allergic reactions, while the *bronchial provocation test (BPT)*, though rarely performed, evaluates airway hyperreactivity. Proper discontinuation of antihistamines and corticosteroids before testing is essential for valid results

5.Treatment Options for House Dust Mite Allergy *(6)*

5.1.Allergen Avoidance

Allergen avoidance aims to reduce exposure to house dust mites by implementing measures such as using allergen-proof bedding, frequent cleaning with HEPA-filtered vacuum cleaners, reducing indoor humidity, and applying acaricides. While these strategies seem beneficial, their clinical efficacy

remains uncertain. Guidelines like ARIA and GINA suggest that no single avoidance measure is likely to significantly reduce HDM exposure or symptoms. However, a combination of multiple strategies may provide better outcomes.

5.2.Pharmacotherapy (Symptomatic Treatment)

Pharmacotherapy is the mainstay for managing HDM-induced allergic rhinitis and asthma, providing symptomatic relief through various medications.

- *Antihistamines* **(second-generation oral and intranasal) help alleviate nasal symptoms.**
- *Corticosteroids* **(intranasal and inhaled) reduce inflammation in the airways.**
- *Leukotriene Receptor Antagonists (LTRAs)* **like montelukast are beneficial, especially for allergic asthma.**
- *Beta-agonists* **(short-acting and long-acting bronchodilators) aid in asthma control.**
- *Anti-IgE Therapy* **(e.g., omalizumab) is used for severe allergic asthma.**

While pharmacotherapy effectively controls symptoms, its benefits cease once treatment is discontinued. Additionally, many available drugs have not been specifically tested for HDM-induced conditions.

5.3.Allergen Immunotherapy (AIT)

Allergen immunotherapy is the only disease-modifying treatment that provides long-term relief even after treatment stops. It includes:

- *Subcutaneous Immunotherapy (SCIT)***: Administered through allergen injections under medical supervision.**
- *Sublingual Immunotherapy (SLIT)***: Delivered as tablets or drops taken under the tongue, with the advantage of home administration.**

SLIT has a better safety profile than SCIT and is gaining popularity due to its convenience. Recent studies indicate that SLIT can significantly reduce the need for inhaled corticosteroids in patients with HDM-induced allergic asthma. However, both SCIT and SLIT require several years of treatment for optimal effectiveness, and patient adherence remains a challenge.

5.4.Combination Therapy and Future Directions

A comprehensive approach that combines allergen avoidance, pharmacotherapy, and AIT may yield the best outcomes for HDM allergy management. Future research should focus on refining immunotherapy protocols, improving diagnostic accuracy, and enhancing treatment adherence. Large-scale, well-designed clinical trials are needed to develop standardized guidelines for HDM allergy treatment.

Conclusion

House dust mites play a crucial role in allergic diseases, particularly allergic rhinitis and asthma, affecting millions worldwide. Their potent allergens disrupt epithelial barriers and trigger chronic immune responses, exacerbating respiratory conditions. Effective diagnosis and management require a combination of accurate allergy testing, environmental control strategies, pharmacotherapy, and immunotherapy. While AIT offers long-term benefits, patient adherence and the variability in treatment outcomes remain challenges. Future research should focus on improving diagnostic accuracy, enhancing allergen immunotherapy protocols, and developing novel interventions to reduce HDM exposure. A multidisciplinary approach integrating environmental, clinical, and immunological perspectives is essential for advancing the management of HDM-induced allergies.

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