MEDICAL IMPACT OF ARTHROPOD ALLERGENS

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Abstract—In the European Union and the USA allergens of arthropods comprise a rising health problem. Atopic diseases resulting from insect or mite exposure cost several hundreds of millions British pounds per European country per year. This article is devoted to major sources of inhalant arthropod allergens, the cause of their rising abundance and resulting morbidity, and possibilities for effective management. For this review, literature was collected from the time period 1900-present.

Arthropod allergens are involved in three different atopic diseases: allergic asthma, allergic rhinitis and atopic eczema. About 40% of the human population has a hereditary predisposition to develop atopic allergies. The atopic diseases show a rising trend in both prevalence and severity. Nowadays, 2–27% (Scandinavia) to 80% (the Netherlands, United Kingdom) of atopic patients are sensitized to one or more allergens derived from arthropods. In the United States up to 70% of asthmatics have a cockroach allergy.

Major arthropods producing relevant allergens include house dust mites, storage mites and cockroaches. Arthropod allergen exposure indoors has increased due to changes in building construction, household management and facility management.

Pesticides may be used to diminish pest populations producing inhalant allergens, but diminishing medical symptoms or preventing sensitization is only possible when the remaining allergens are removed by cleaning.

The prevention of atopic disease demands avoidance in both the domestic and the occupational domain. Responsibility for the prevention and management of arthropod derived disease in the domestic environment is shared between the householder and owner of the dwelling. Health professionals have an advising and therapeutic role. In the occupational domain, architect, facility manager, work manager and employee share responsibility for prevention and care.

In the domestic and occupational domains different multidisciplinary Task Groups should be formed to solve the problem of arthropod allergens. Pest exterminators have a (public) health task in both domains.

INTRODUCTION

The presence of arthropod pests in the urban environment results in a variety of medical problems. These organisms are renowned vectors of bacterial and viral infections, and of food poisoning microbes. Adequate management and efficient use of pesticides have reduced the impact of these diseases (Patton and Evans, 1929; Burgess, 1990). In addition, arthropods secrete or excrete allergens provoking two different types of allergic diseases: atopy and insect venom allergy (Mygind et al., 1996; Müller & Mosbech; 1993). This contribution will be restricted to inhalant allergens causing atopic disease.

Allergy means 'unusual reacting'. The term is used to describe the reaction on a substance that is generally not harmful, but causes an immune reaction giving rise to symptoms and diseases in some individuals (Mygind et al., 1996). Such a substance is called an allergen. Allergens originate from different substances: pollen of plants and trees, moulds, food, and animal parts and products.

Atopy is a so-called Type-I allergy: IgE-mediated and with immediate phenomena (Mygind et al., 1996). At first contact with an allergen, special antibodies of the IgE-class against the allergen are produced in blood and tissues. In case of a subsequent exposure these IgE-antibodies have a medical impact within 20–30 minutes after contact. Several hours later, delayed-type reactions may occur in addition.

In the last decades, the prevalence and severity of atopic allergies have risen in both the European Union and the USA (Mygind et al., 1996; Platts-Mills, 1992). Figures for mortality due to allergic diseases amount to 3 to 4 per 100,000 individuals per year for asthma in UK and 1 per 100,000 in the Netherlands respectively (Platts-Mills, 1992; Centraal Bureau voor Statistiek, 1993). Costs of allergic disorders accumulate to several hundreds or even billions of British pounds per year per European country, due to extensive use of health services and a high incidence of allergy related sick leave (Colloff et al., 1992; van Mölken et al., 1989).
In this article we will describe the most relevant sources of arthropod allergens causing atopic disease and focus on the role of arthropods in the increasing prevalence and severity of allergic diseases. Finally, we will discuss how exposure to arthropod allergens in domestic and occupational environments may be reduced below hygienic thresholds by multidisciplinary teamwork of different Partners-in-Care.

LITERATURE SEARCH

Literature was collected with the aid of Index Medicus (1966 - april 1996) and the reprint collection (1900–1985) of the Interuniversity Task Group ‘Home and Health’, Utrecht/Eindhoven, The Netherlands. References were reviewed that contained the keywords ‘allergen’ or ‘allergy’, combined with one of the following: insect, arthropod, mite, house dust, storage, cockroach, locust, silverfish, dust lice, silk worm, midge, chironomid, carpet beetle, occupational, work, laboratory, and environmental.

ATOPIC DISEASES

Atopic diseases are allergic asthma, atopic dermatitis, and allergic rhinitis. The prevalence of atopic disease in relation to arthropods is considerable (Table 1). About 40% of the human population have a hereditary predisposition to atopy, a so-called atopic constitution (Bronswijk, 1991). The inherited atopic constitution is polygenic and complex (Mygind et al., 1996). A child inherits a predisposition for: (1) atopic disease in general; (2) involvement of certain organs; and (3) severity of the symptoms. A child of parents with severe asthma is therefore at greater risk of developing asthma than a child of parents with mild rhinitis (Mygind et al., 1996; Bousquet and Kjellman, 1986). The relevance of arthropod pests in allergy can be understood from the hereditary predisposition of allergic diseases and the allergic sensitization to arthropod products.

Sensitization to allergens and a subsequent development of disease only occurs after prolonged exposure to allergens that may take place by inhalation, by skin contact or by ingestion (Colloff et al., 1992). In essence all species of arthropods are candidates for medically relevant allergens. In practice the length and massiveness of actual individual exposure governs medical importance (Platts-Mills, 1992). Sensitization to a specific allergen is demonstrated using blood tests, skin tests or allergen provocation tests.

The risk of sensitization is increased by exposure early in life (Sporik et al., 1990). Children born in autumn when dust mite allergens are at peak levels, have a higher risk of sensitization to dust mite allergens than those born in other seasons (Warner and Price, 1978, Mygind et al., 1996). More than half of sensitized persons will develop an atopic disease (Mygind et al., 1996).

Allergic asthma

Allergic asthma is a chronic inflammatory disease of the airways, in which bronchus obstruction occurs as a reaction on a variety of exogenous factors such as allergens, irritants, exercise and viral infections (Sheffer, 1992). Of these factors, allergens are considered to play the major role (Colloff et al., 1992). The prevalence rate of atopic asthma is rising in Western Europe and North America.

Table 1. Prevalence of atopic diseases in Western Europe and North America (Mygind et al., 1996)

<table>
<thead>
<tr>
<th>Disease</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergic asthma</td>
<td>5–10%</td>
</tr>
<tr>
<td>Atopic dermatitis*</td>
<td>10–15%</td>
</tr>
<tr>
<td>Allergic rhinitis</td>
<td>10–20%</td>
</tr>
</tbody>
</table>

*Cumulative prevalence
Medical impact of arthropod allergens

(Blumenthal et al., 1993; Mygind et al., 1996). Asthma is nowadays considered to be the most common chronic disease in children in the western world (Mygind et al., 1996).

Asthma usually becomes evident at the age of 3–5 years. Its prevalence has two peaks: in childhood and during adult life. In women, the second peak occurs before the age of 30, while for men it is seen at the age of 50 (Mygind et al., 1996; Nelson, 1991). During adolescence, asthma improves in 50% of cases, predominantly the mild ones. In 30% of the patients it returns during adult life (Mygind et al., 1996).

The severity of asthma increased in the last decades as demonstrated by hospital admission rates in England, Wales, and the USA (Blumenthal et al., 1993). Although asthma death rates remain low (4/100,000/year in the UK and 1/100,000/year in the Netherlands (Platts-Mills, 1992, Centraal Bureau voor Statistiek, 1993)), the mortality associated with asthma has risen lately, especially among asthmatic children (Jackson et al., 1988).

In the Netherlands, about 20% of all work absenteeism and more than 20% of school absenteeism is related to asthma (Kersten and Ewalts-Willers, 1987). Total economic costs (National Health Services, sickness benefit, research, lost productivity and earnings) of asthma in the Netherlands amounted to 1.027 million Dutch guilders (approximately 350 million British pounds) in 1990 (van Molken et al., 1989). In the United Kingdom the total economic costs were estimated to be 946 million British pounds in 1987 (Colloff et al., 1992).

Allergic rhinitis

Allergic rhinitis is also an atopic disease. It consists of inflammation of the nasal mucosa and is characterized by a mucous membrane hyper-reactive to allergens and irritants. Rhinitis has been defined as a combination of sneezing, discharge and blockage, lasting ≥1 hour in most occasions (Mygind et al., 1996).

Allergic rhinitis is diagnosed from the age of 4 or 5 years upward. Prevalence of the disease increases to reach 10–15% in adolescence. Allergic rhinitis is rare in individuals over 65 years of age (Lund, 1994).

The prevalence of allergic rhinitis is increasing (Mygind et al., 1996, Lund, 1994). Allergic rhinitis appears to be more common in urban than in rural areas. In Denmark the prevalence of allergic rhinitis among patients attending general practitioners was 19% in Copenhagen and 6–14% in surrounding rural areas (Pedersen and Weeke, 1981). In the USA, 75% of allergic rhinitis cases resided inside the city, compared to 25% who lived in the surrounding rural region (Broder et al., 1974).

Most rhinitis patients have mild to moderate symptoms (Mygind et al., 1996). In severe cases, the disease can interfere with the patient’s daily activities, school or work performance. Although the direct societal costs of rhinitis may not be high, as few patients require hospitalisation or extensive use of health services, the economic impact on patients may be considerable, due to loss of earnings attributable to sick leave and reduced productivity, and the financial burden of special avoidance measures. In addition, medication may not be available through national health or personal insurance schemes (Lund, 1994).

Atopic eczema

Atopic eczema is also called atopic dermatitis. This inflammatory skin disorder has a chronic, relapsing course. It is characterized by itching, leading to scratching and excoriations (Mygind et al., 1996).

Based on the age of the patient and distribution of the eczema lesions over the skin surface, atopic dermatitis has three stages. In the infantile stage from 2 months to 2 years of age, cheeks and scalp are first affected. During exacerbations, lesions spread to neck, trunk, arms and legs. In the childhood stage, age 4 to 10, the eczema is more localized, typically involving the flexural sides of elbows and knees. From the age of 12, the adult stage sets in. In this stage, the head and neck are often involved. In 90% of patients the infliction develops within the first 3 years of age. Symptoms usually diminish and disappear in 80% of the cases during adolescence (Mygind et al., 1996).

The cumulative prevalence rate of atopic dermatitis has increased worldwide over the last three decades from 2–3% before 1960 to 10–15% nowadays (Schultz Larsen and Hanifin, 1992).
The total economic cost of atopic dermatitis (including contact dermatitis) in the Netherlands can be estimated at 32 million Dutch guilders a year (12 million British pounds) (Ruwaard and Kramers, 1993). Similar to atopic rhinitis, the direct societal costs of eczema may not be high, however, in individual cases costs may be considerable.

ALLERGENS AND ARTHROPODS

Atopic diseases are provoked by allergens. The association between sensitivity to arthropod allergens and atopic diseases is strong. In up to 80% of disease cases arthropods are (partly) responsible (Table 2).

A summary of the most common inhalant arthropod species involved in inhalant allergic diseases is listed in Table 3. Arthropod allergens that are already purified and named are listed in table 4.

Exposure to arthropod allergens is more extensive in the domestic as compared to the occupational environment. There are two reasons: (a) the humidity is generally higher in the domestic environment due to a higher water vapour production (cooking, bathing and washing), giving more insects and mites developmental possibilities, and (b) the exposure period is longer in the domestic environment as compared to the occupational domain. The exact nature and intensity of additional occupational exposure to arthropod allergens depend on the type of working environment. In general, indoor exposure to arthropod allergens has increased in the last 20 years due to energy saving campaigns, leading to less ventilation and resulting in improved (more humid) conditions for arthropods (Wickman et al., 1993).

In essence the office and hospital environment are comparable to the domestic environment, with the exception of a lesser role for house dust mites (Janko et al., 1995). Other occupations may call for intensified contact with special arthropods or arthropod products (Table 3).

Domestic environment

In cases of diseases originating in the domestic environment, the tenant (household) has the primary responsibility for prevention and care. In addition, the owner of the dwelling takes responsibility for the physical state of the building, by keeping it unattractive to arthropods. Health-care professionals, such as the family nurse in the Netherlands and in the UK (Bronswijk et al., 1994; Hobbs and Lenney, 1994), provide information and guidance on the health aspects of pests and on keeping allergen exposure low in cases of atopy.

Mites

Mites are small arachnids, measuring 0.1–1 mm in length. In the domestic environment, more than a 100 mite species have been found. Most common and abundant are: Pyroglyphids, Acarids, Glycyphagids, predatory mites and Oribatids (Bronswijk, 1981).

Table 2. Prevalence (in %) of sensitization for arthropod allergens in allergic patients in different areas of Western Europe and North America

<table>
<thead>
<tr>
<th>Arthropod allergens</th>
<th>European Union</th>
<th>North America</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>United Kingdom</td>
<td>Netherlands</td>
</tr>
<tr>
<td>House dust mites</td>
<td>80^1</td>
<td>80^2</td>
</tr>
<tr>
<td>Storage mites</td>
<td>&gt; 30^6</td>
<td>65–70^7</td>
</tr>
<tr>
<td>Cockroaches</td>
<td>10^11</td>
<td></td>
</tr>
</tbody>
</table>


Table 3. Arthropod species causing atopic disease in domestic and occupational environments.

<table>
<thead>
<tr>
<th>Arthropods</th>
<th>Scientific name</th>
<th>Common name</th>
<th>Domestic/Occupational</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INSECTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Acheta domesticus</em> (Linnaeus)</td>
<td>House cricket</td>
<td>D/O</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><em>Alphitobius diaperinus</em> (Panzer)</td>
<td>Lesser mealworm</td>
<td>O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Apis mellifera</em> Linnaeus</td>
<td>Honey bee</td>
<td>D/O</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>Blatta orientalis</em> Linnaeus</td>
<td>Oriental cockroach</td>
<td>D/O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Blattella asahinai</em> Mizukubo</td>
<td>Asian cockroach</td>
<td>D/O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>B. germanica</em> (Linnaeus)</td>
<td>German cockroach</td>
<td>D/O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Bombyx mori</em> Linnaeus</td>
<td>Silk worm</td>
<td>O</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td><em>Chironomus plumosus</em> (Linnaeus)</td>
<td>Chironomid midge</td>
<td>D/O</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><em>C. thummi</em> (Meigen)</td>
<td>European midge</td>
<td>D/O</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td><em>Callosobruchus maculatus</em> Fabricius</td>
<td>Bruchid beetle</td>
<td>O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Cladoranytarsus letvisi</em> (Freeman)</td>
<td>'Green nimitti' midge</td>
<td>D</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td><em>Cocylonaiadus~ americanus</em> (Coquerel)</td>
<td>Screwworm/American fly</td>
<td>O</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>Daphnia pulex</em> (De Geer)</td>
<td>Water flea</td>
<td>D/O</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>Drosophila melanogaster</em> Meigen</td>
<td>Fruit fly</td>
<td>O</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td><em>Ephemerida danica</em> Muller</td>
<td>May fly</td>
<td>D</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td><em>Ephesia kuehniella</em> (Zeller)</td>
<td>Mediterranean flour moth</td>
<td>O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Galleria mellonella</em> (Linnaeus)</td>
<td>Large bee moth</td>
<td>O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Lepisma saccharina</em> Linnaeus</td>
<td>Silverfish</td>
<td>D</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td><em>Liposcelis bohar</em> Badonnel</td>
<td>Dust (book) louse</td>
<td>D</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td><em>Locusta migratoria</em> Linnaeus</td>
<td>Migratory locust</td>
<td>O</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td><em>Macronema radiatum</em> Pictet</td>
<td>Caddis fly</td>
<td>D/O</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td><em>Musca domestica</em> Linnaeus</td>
<td>Common house fly</td>
<td>D</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td><em>Periplaneta americana</em> (Linnaeus)</td>
<td>American cockroach</td>
<td>D/O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Psychoda alternata</em> Latreille</td>
<td>Sewer fly</td>
<td>D/O</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td><em>Schistocerca gregaria</em> Forskal</td>
<td>Desert locust</td>
<td>O</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Sitophilus granarius</em> (Linnaeus)</td>
<td>Grain weevil</td>
<td>O</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td><em>Tenebrio molitor</em> Linnaeus</td>
<td>Common meal beetle</td>
<td>O</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td><em>Trogoderma angustum</em> Solier</td>
<td>Berlin carpet beetle</td>
<td>O</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><em>Vespula germanica</em> (Fabricius)</td>
<td>German wasp</td>
<td>D</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>V. vulgaris</em> (Linnaeus)</td>
<td>Common wasp</td>
<td>D</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>Zabrotus subfuscatus</em> (Boheman)</td>
<td>Mexican bean weevil</td>
<td>O</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>MITES</strong></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acarus siro</em> (Linnaeus)</td>
<td>Storage mite</td>
<td>D/O</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><em>Blomia tropicalis</em> van Bronswijk, de Cock, Oshima</td>
<td>Storage mite</td>
<td>D/O</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><em>Dermatophagoides farinace</em> Hughes</td>
<td>American house dust mite</td>
<td>D</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><em>D. microceras</em> Griffiths &amp; Cunningham</td>
<td>House dust mite</td>
<td>D</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><em>D. pteronyssinus</em> (Trouessart)</td>
<td>European house dust mite</td>
<td>D</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><em>Euroglyphus maynei</em> (Cooreman)</td>
<td>House dust mite</td>
<td>D</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><em>Glycyphagus domesticus</em> (De Geer)</td>
<td>Storage mite</td>
<td>D/O</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><em>Lepidoglyphus destructor</em> (Schrank)</td>
<td>Storage mite</td>
<td>D/O</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><em>Ornthonyssus sylviarum</em> (Canestrini &amp; Fanzago)</td>
<td>Northern fowl mite</td>
<td>O</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>Tyrophagus putrescentiae</em> (Schrank)</td>
<td>Storage mite</td>
<td>D/O</td>
<td>8.1</td>
<td></td>
</tr>
</tbody>
</table>


House dust mites are members of the mite family Pyroglyphidae. They account for more than 90% of the mite population in textiles in dwellings in the European Union and the USA (Platts-Mills, 1992; Bronswijk, 1981). Cosmopolitan species include *Dermatophagoides farinaceae, D. microceras, D. pteronyssinus* and *Euroglyphus maynei*. Pyroglyphids are comparatively small (0.1-0.5 mm in length).

Population growth of pyroglyphids requires protein-rich food, a relative humidity (RH) of 50% or more, and indoor temperatures between 10 and 30°C. They survive a temperature range of...
−28°C for six hours to +60°C for 1 hour (Bronswijk, 1981). Since human individuals shed 0.5–1.0 gram of mite edible skin scales a person every day (Voorhorst and Spieksma, 1972), mite food is not a restrictive factor. The niches of these mites are formed by textile materials such as beds, carpets, upholstered furniture, soft toys, and clothing (Platts-Mills, 1992). However, the potential for mite breeding (and hence the amount of allergen produced) is related to the micro-climate found in a particular home textile (Nes et al., 1993).

There exists a seasonal variation in mite numbers and amount of mite allergens. In Western Europe maximum levels of living mites are seen in June. Dead mite counts have their peak value in August-September, while highest allergen concentration is reported from August to December. The lowest level of both mite and allergen concentrations may be measured between February and May (Vervloet et al., 1982; Platts-Mills et al., 1987). The decrease is due to lower indoor air humidities in the cold winter months (Nes et al., 1993).

In countries with a moderate climate such as the United Kingdom and the Netherlands up to 80% of atopic patients have strongly positive skin tests to mite extracts (Sarsfield, 1974; Bronswijk et al., 1994). In the colder and drier Scandinavian countries house dust mite allergy is less common. In northern Sweden 2% of atopic children appeared to be sensitized to house dust mite, whereas in southern Sweden 12% were sensitized (Wickman et al., 1993).

At least 12 different allergens of house dust mites have been characterized (Table 4). Of these, the so-called Group I and Group II allergens are the most important: more than 80% of mite-allergic patients have IgE antibodies against these groups (Platts-Mills, 1992). A house dust mite produces 2–4 ng Group I allergen and about 1–2 ng Group II allergen per day (Colloff et al., 1992).

Allergens of Dermatophagoides species are formed in the posterior midgut and the hindgut as digestive enzymes (Bronswijk, 1981), excreted in faecal pellets (10–40 μm in diameter) and in shed skins of mites. These allergenic parts are relatively large and will rapidly fall in undisturbed air (Platts-Mills, 1992, Platts-Mills et al., 1991). However, in time the excrement pellets will crumble and become more easily airborne (Bronswijk, 1981).

In dwellings storage mites usually belong to the families Acaridae and Glycyphagidae. Typical species include Acarus siro, Glycyphagus domesticus, Lepidoglyphus destructor and Tyrophagus putrescentiae (Kort, 1994). Storage mites feed on fungi. In urban areas they are found in low quantities in home-textiles and in higher quantities on fungal ridden wall and ceiling surfaces (Kort, 1994). They are more desiccation-sensitive than house dust mites and need a continuously humid environment for fast development, with a relative humidity of 70 to 98% (Bronswijk, 1981).

On a global scale exposure rates to both pyroglyphid and storage mites vary according to altitude (Vervloet et al., 1982; Charpin et al., 1991), latitude (Bronswijk, 1981, Munir et al., 1995) and continentality (Bronswijk, 1981; Munir et al., 1995), all influencing indoor air humidity. Exposure rates to house dust mite products in urban and rural areas are rising in Western Europe and the USA. Energy saving measures in these temperate climate zones have induced a more humid indoor climate, favourable to moulds and mites (Wickman et al., 1993). In addition dust reservoirs became more extensive, due to the widespread practice of wall-to-wall carpeting that are not cleaned in depth in domestic, school and office environments (Custovic et al., 1994).

The story of storage mites in Western European dwellings is more complicated. Before World

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**Table 4.** Identified arthropod allergens (after Piao King et al., 1995)

<table>
<thead>
<tr>
<th>Allergen</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bla g I, g II</td>
<td>INSECTS Blattella germanica</td>
</tr>
<tr>
<td>Chi t I</td>
<td>Chironomus thummi thummi</td>
</tr>
<tr>
<td>Per a I</td>
<td>Periplaneta americana</td>
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<tr>
<td>Der f I,II,III</td>
<td>MITES Dermatophagoides farinae</td>
</tr>
<tr>
<td>Der m I</td>
<td>D. microceras</td>
</tr>
<tr>
<td>Der p I-VII</td>
<td>D. pteronyssinus</td>
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<tr>
<td>Lep d I</td>
<td>Lepidoglyphus destructor</td>
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</table>
War II, allergy due to storage mite exposure was not uncommon in the urban environment (Kort, 1994). In the sixties, urban dwellings were usually too dry to support extensive population growth. In that time period exposure to storage mites was an occupational problem (in old and mouldy grain products), seen in rural surroundings only (Kort, 1994). After the energy crisis (1973), and the resulting increased humidity indoors, mould and storage mite growth on walls and ceilings became common. Combined with less-intensive house-cleaning procedures (as mentioned above) exposure to storage mites increased. From the eighties onward storage mite allergy was reintroduced into the urban population (Kort, 1994).

Cockroaches

Most common in Europe is the German cockroach *Blattella germanica*. In the United States the American cockroach *Periplaneta americana* and the oriental cockroach *Blatta orientalis* are abundant (Garcia et al., 1994). Cockroaches are omnivorous, but prefer sweet, humid and carbohydrate rich food (Stichting Vakopleiding Ongediertebestrijding, 1993).

Although exposure to cockroach allergens is more common in the USA, exposure to these allergens is becoming a medical problem in European countries too (Bessot et al., 1994). Cockroaches are found in private dwellings, as well as in public environments with access to food such as restaurants, grocery stores, bakeries, hotels, hospitals, on board ships and on rubbish dumps (Stichting Vakopleiding Ongediertebestrijding, 1993).

Cockroach allergies are especially common in crowded multifamily dwellings in deprived urban areas (Kang and Sulit, 1978; Gelber et al., 1993; Garcia et al., 1994). The increased number of flats equipped with air heating and block heating gives cockroaches more shelter and migrating possibilities. These heating systems connect all living units in a flat, creating entrances between dwellings. This also complicates effective treatment with pesticides (Stichting Vakopleiding Ongediertebestrijding, 1993). The prevalence of sensitization to cockroach in atopic patients is about 10% in Europe and 7–69% in the USA (Kang and Sulit, 1978; Bessot et al., 1994).

The allergens of cockroaches include specific ones for a single cockroach species as well as shared allergenic components of different taxa (Helm et al., 1990, Stankus and O’Neil, 1988). Cockroach allergens are found in their faeces as well as in shed skins and different body parts. The proteins derived from epithelial cells of the intestinal tract and the Malpighian vessels, equivalent in function to kidneys, are assumed to be the most important allergens of cockroach allergy (Zwick et al., 1991).

Silverfish

Silverfish belong to the family Lepismatidae. They measure 3–12 mm, have 3 tail appendages and are covered with shiny scales. The common silverfish *Lepisma saccharina* prefers dark and humid (relative humidity above 75%) places in the home, and may be found in any room or indoor space. They feed primarily on carbohydrates: starched cloth, bookbindings, wallpaper paste, and stored grains (Stichting Vakopleiding Ongediertebestrijding, 1993).

54–69% of atopic patients are sensitive to silverfish (Rijckaert, 1981, Bronswijk et al., 1994). No specific allergens of silverfish have yet been purified and named. Research on the silverfish allergens is in progress at the Central Laboratory of the Red Cross Blood Transfusion Service in Amsterdam, The Netherlands (Witteman, 1995).

Dust lice

Dust (or book) lice belong to the order Psocoptera. They measure up to 4 mm, and have a white, grey or brown colour. Although some species have wings, they are not able to fly. Their jerky way of walking is characteristic (Stichting Vakopleiding Ongediertebestrijding, 1993). Dust lice avoid light and thrive at relative humidities of 80% or more, and a temperature between 20°C and 25°C (Stichting Vakopleiding Ongediertebestrijding, 1993). They devour moulds (Stichting Vakopleiding Ongediertebestrijding, 1993), making them common in modern humid housing (Kort et al., 1989).
34–63% of atopic patients are sensitive to dust lice (Bronswijk et al., 1994; Rijckaert, 1981). The effect of cross-reactivity with allergens of other arthropods such as the fungi-devouring storage mites needs to be studied.

Occupational environment

Some occupations result in a massive exposure to certain allergens, inducing specific work-related allergies. As high risk occupations we selected the pest exterminator, employees of insect and mite laboratories, farmers and other workers in the food processing industry, workers in the silk industry, and sewage handlers (compiled from Moscato and Dellabianca, 1994, Kagen, 1990).

Pest extermination services

For the pest exterminator working in and around dwellings, cockroaches and carpet beetles (Trogoderma angustum) are the main target for extermination (Stichting Vakopleiding Ongediertebestrijding, 1993). The prevalence of allergies against these arthropods in pest exterminators is not mentioned in the literature. In atopics in the general population sensitization to carpet beetles amounts to 35% (Klaschka and Rudolph, 1980).

Insect and mite laboratories

Laboratory workers occupied with breeding or testing arthropods were reported to have a high incidence of atopic disease due to allergens of the grain weevil (Frankland and Lunn, 1965), the larvae of the bee moth (Stevenson and Mathews, 1967), locusts (Burge et al., 1980; Frankland, 1953), chironomid midges (van Kampen et al., 1994) and cockroaches (Steinberg et al., 1987). See also Table 3.

Farming and food processing industry

In farm houses storage mites are found more often and in larger numbers than in urban dwellings, due to infested straw, hay and animal feed (van Hage-Hamsten, 1992). However, in the barn-area changes in agricultural practice will lead to a diminishing of occupational storage mite exposure (Kort, 1994). This will eventually affect dairy farmers who are nowadays abundantly allergic to storage mites (van Hage-Hamsten et al., 1985). Occupation-specific allergic disease among poultry farmers concerns the northern fowl mite, a blood sucking parasite of fowl, producing allergen-containing excreta abundantly (Kagen, 1990).

Not only farmers are exposed to the arthropods living in foodstuffs and fodder, but also shipping workers (asthma due to grain mites and insects (Sheffer, 1992)), granary workers (itch or asthma due to storage mites (Sheffer, 1992)), bean sorters (atopic disease caused by the Mexican bean weevil (Wittich, 1940)), or employees in the fish food manufacturing industry (atopic disease due to midges (Sheffer, 1992)).

Silk industry

In the textile industry, silk production and processing result in an extensive exposure to allergens of the silk worm and moth. A high incidence of atopic disease is the result. Sensitization to silkworm-derived allergens is common among silkwokers (prevalence 12–52% (Harindranath et al., 1985)).

Sewage handling

Sewage handling plants are attractive to Psychoda species, locally known as sewage filter flies or sewer flies. Their numbers may be enormous during warm months (spring until fall). Ordman (1946) and Gold et al. (1985) report asthma caused by sewer flies Psychoda alternata in sewage plant workers.
MANAGEMENT OF ARTHROPOD ALLERGENS

Effective management of arthropod allergies is required. Epidemiological studies in western countries have shown increasing prevalence rates of allergic asthma, allergic rhinitis and atopic dermatitis since the twenties (Dekker, 1930, Dekker, 1928; Mygind et al., 1996), particularly in childhood and adolescence (Blumenthal et al., 1993). In the Netherlands this trend is expected to continue into the next decade (Ruwaard and Kramers, 1993).

Since a change in genetic factors cannot occur over a few decades, the explanation of the increase in atopic diseases must be sought in environmental factors (Mygind et al., 1996). The simultaneous increase in exposure to arthropod allergens, in consumption of exotic fruits, and the decrease in infant exposure to infections, indicate a multifactorial cause, with arthropod allergens playing an important role (Charpin and Vervloet, 1992).

Stopping the increase in allergies, as well as preventing new individual sensitizations and the development of allergic complaints, form the justifications of allergen management programs. A significant reduction of arthropod allergens has become a major goal in the management of allergic disease (Bronswijk, 1995). As has been mentioned before both the domestic and the occupational environment are relevant (Janko et al., 1995).

Hygienic limits

At the base of an effective allergen management program stands the establishment of hygienic exposure limits for sensitization and for the development of allergic symptoms. Until now these threshold levels have been established for mites and cockroaches only. Allergen management programs are effective if allergen concentrations remain below these thresholds. For the allergens produced by other arthropods no hygienic thresholds have been established. A management program for these species will aim at the maximum reduction technically possible.

Mite allergen exposure is measured in settled dust as mite allergen concentration, number of mite bodies, or guanine concentration (Platts-Mills, 1992). Guanine is the nitrogen excretion product of arachnids and correlates well with mite allergen concentrations in the indoor environment (Colloff et al., 1992, Platts-Mills, 1992). For house dust mites the threshold level for sensitization has been set at 2 μg of group I mite allergens or 0.6 mg guanine per gram settled dust, 100 mites per gram bed dust, or 10 mites per gram floor dust (Platts-Mills and de Weck, 1989; Bronswijk, 1988). The threshold level for the development of an acute asthma attack in mite-allergic persons is 10 μg of Der p I or 3.0 mg of guanine per gram settled dust, or 500 mites per gram bed dust (Platts-Mills and de Weck, 1989). The threshold level for sensitization to cockroaches was proposed at 2–8 ng Bla g II allergen per gram dust (Gelber et al., 1993; Call et al., 1992).

Pest extermination

Removal of pests with or without pesticides forms the heart of a management plan for arthropod allergens. Effective pesticides against mites and cockroaches include benzyl benzoate, chloropyrifos, and synthetic pyrethroids (Stichting Vakopleiding Ongediertebestrijding, 1993; Schober et al., 1992). Unwashable objects, such as furniture, may also be treated with pesticides against house dust mites, in combination with moist cleaning, including vacuum cleaning to remove the loosened dirt. Storage mites living on mouldy spots on walls and ceilings are removed by the application of peroxide containing products (Kort et al., 1993). Pesticides with a high sensitization potency, such as natural pyrethrins, are not acceptable in dwellings of atopic patients (Bismuth et al., 1987).

Against house dust mites, washing at 60°C is most effective (Colloff et al., 1992; Bronswijk et al., 1994). The mites will be killed, and with the rinsing water dead mites as well as mite allergens are removed from textiles. Vacuum cleaning will not remove live mites out of home textiles. House dust mites cling strongly to the fibres of the home textile (Colloff et al., 1992).

Washable textiles that do not tolerate high temperatures can be treated effectively by freezing at -20°C during one week followed by washing at a low temperature to remove killed mites and active mite allergens. Both treatments should be repeated at a six weekly interval, in case the indoor climate is appropriate for the proliferation of mites (Bronswijk, 1981).
Reduction of inhalant allergens

Pesticides diminishing arthropod populations are not effective in preventing sensitization, development of disease, or health complaints. The remaining allergens have to be removed, e.g. by thorough wet or moist cleaning, before a clinical effect becomes evident (Colloff *et al*., 1992). Washable or cleanable smooth surfaces of floors, walls, ceilings and furniture, avoidance of cracks and crevices, and barrier covers around bed parts prevent the build-up of allergens, at the same time facilitating the required cleaning program (Colloff *et al*., 1992; Bronswijk *et al*., 1994).

Inactivation of arthropod allergens is attempted by application of tannine or tannate formulations to textiles. The effectiveness of this procedure has been studied with RAST inhibition tests. However, doubts on efficacy in vivo remains, since these preparations also denature enzymes used in the RAST-inhibition test (Koren, 1995).

A management concept for the domestic environment

Various disciplines are involved in avoidance of exposure to arthropod allergens (Figure 1. Unfortunately, hindered by feelings of shame, not all infested dwellings are presented for treatment. This decreases the effectiveness of extermination actions, especially in cases of cockroach infestation where whole blocks of dwellings should be treated together (Stichting Vakopleiding Ongediertebestrijding, 1993). Pest extermination personnel are best equipped to inform the public about arthropod pests in an open way, reaching all target groups.

Effective allergen avoidance is a step-by-step procedure with several Partners-in-Care (Bronswijk *et al*., 1994) (Figure 1). First of all the patient and other members of the household should be motivated by the treating physician through assessing the degree of health improvement to be expected from an effective avoidance. Disadvantages of avoidance for household members include the effort in time and costs needed – actual avoidance motivation is a balance between advantages and disadvantages for the household members (Custovic *et al*., 1994).

The physician takes responsibility for diagnosing sensitizations and hyper-reactivities. In addition to indoor allergens and irritants, food allergens and outdoor allergens (pollen and some insects) are taken into account in the diagnosing process. The physician further prescribes drug treatment, and periodically evaluates the clinical effect of both medication and allergen avoidance measures (Bronswijk *et al*., 1994; Bronswijk, 1995).

The second step in arthropod allergen avoidance includes assessment of actual exposure, using a structured interview by a community nurse, over-the-counter tests, or laboratory techniques. In the Netherlands the household is supported by a community nurse, not only for exposure assessment, but also for choosing from the different effective measures and for a structured and feasible allergen avoidance program.

<table>
<thead>
<tr>
<th>Responsibilities Partners-in-Care</th>
<th>Diagnosing arthropod allergies</th>
<th>Estimating exposure</th>
<th>Extermination &amp; cleaning</th>
<th>Prevention</th>
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</thead>
<tbody>
<tr>
<td>Patient</td>
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<tr>
<td>Household</td>
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<tr>
<td>Physician</td>
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<tr>
<td>Community nurse</td>
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<tr>
<td>Pest exterminator</td>
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<td>Cleaning service</td>
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<td>Building engineer</td>
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Figure 1. Partners-in-care in arthropod allergen avoidance in the domestic environment and their responsibilities.
avoidance program (Bronswijk, 1995).

The frequency of large scale surface treatment with pesticides or cleaning against allergens can be reduced by taking preventive measures, pursuing one or more of four tools that influence living conditions of the arthropods concerned: no entrance, no food, no shelter, no appropriate climatic conditions (Stichting Vakopleiding Ongediertebestrijding, 1993).

Relative humidity is the most important restricting factor for mite population growth. Human beings need a relative humidity between 30–70% to feel comfortable. When indoor air humidity remains below 50% for several weeks mites will die (Brandt and Arlian, 1976, Maessen, 1995). By combining adequate ventilation and heating with a reduction of water vapour production through household activities, relative indoor air humidity will decrease, making living conditions for mites less favourable. In this way, in temperate regions, the diminished water vapour content indoors will result in a relative humidity below 50% during the cold winter months (Nes et al., 1993).

Successful extermination of allergen producing cockroaches needs the expertise of the pest exterminator. When necessary the help of cleaning services can be called in. For prevention of cockroach infestation it is important to reduce cockroach entry routes to a minimum. Block heating and hot air heating are important access routes. Cooperation of pest exterminator and HVAC engineer, will result in structural improvements (Seifert, 1991).

At half-yearly intervals household members or the community nurse should check to confirm that exposure levels remain below hygienic thresholds. If not the avoidance program should be repeated (Bronswijk, 1995).

Public buildings should be suitable to most possible users (Harber et al., 1995). Here management of arthropod allergens is mainly of a global preventive nature. This is in contrast with the situation in the private, domestic domain that is only meant for family and friends. No law prevents individual household members from behaving in an unhealthy manner, e.g., by keeping arthropod-prone conditions in the dwelling. Usually allergen avoidance management takes place after sensitization, disease or symptoms have developed (Colloff et al., 1992).

Management in the occupational environment

To prevent allergic manifestations due to work, different Partners-in-Care are called for. Fundamentally, five partners are responsible for the well-being of the employee at work: architect and building engineer, facility manager, manager of the organisation, the medical services of the organisation, and the employee themself (van der Poest Clement and Boere, 1994).

The individual worker is responsible for his or her own private health (Harber et al., 1995). We may expect worker reports to the medical services of the organisation and managers, any allergies or health complaints experienced. The manager of the organisation takes responsibility for all working procedures and the assessment of health damage that could be evoked through these procedures (Harber et al., 1995). The medical service of the organisation should -when possible-remove the worker from harmful exposure. When the worker has to stay in the same working environment, the industrial hygienist should supply information on the use of protective devices to minimize exposure, e.g., dust masks or respirators (van der Poest Clement and Boere, 1994).

Facility managers coordinate all efforts relating to planning, design and management of buildings, including systems, equipment and furniture (Wagenberg, 1996). Their duties encompass setting health standards and contracting pest exterminators and cleaning services to attain these standards.

Architects and building engineers may, by design and materialization of the building, take precautions to prevent access by pests, and to make the building easily cleanable, while securing adequate ventilation capacity to keep the indoor air dry and clean.

CONCLUSIONS

In the past, the medical impact of arthropods was mainly associated with vector status for infectious micro-organisms and microbes causing infectious diseases and food-poisoning. But nowadays in Western Europe and North America, produced allergens have a greater impact on
(public) health. Increased exposure to arthropods plays a role in the rising prevalence of atopic diseases in the European Union and the USA.

House dust mites, storage mites and cockroaches are the main arthropods relevant to allergic disease. Other pests in the domestic and occupational environment, and species reared in biological laboratories are of lesser public health importance. Energy saving programs, changed cleaning regimens, block and air heating systems have created more favourable living conditions for allergenic arthropods or increased allergen exposure of man.

In prevention and treatment of arthropod allergies, reduction of exposure to below hygienic thresholds plays a role of increasing importance. It can best be performed by multidisciplinary teamwork between patient, household members and professionals of various disciplines.

In the domestic domain a structured cooperation of pest exterminator, patient, other household members, cleaning services, building engineers, medical doctors and the family nurse is needed to tackle daily health problems. In the occupational environment the architect of the premises, the facility manager and the manager of the organisation should work together to prevent sensitization and disease due to ‘occupational’ arthropods.

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