

Effectiveness of Vacuum Cleaning and Wet Cleaning in Reducing House-Dust Mites, Fungi and Mite Allergen in a Cotton Carpet: A Case Study

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(Accepted 30 July 1986)

ABSTRACT

Wassenaar, D.P.J., 1988. Effectiveness of vacuum cleaning and wet cleaning in reducing house-dust mites, fungi and mite allergen in a cotton carpet: a case study. *Exp. Appl. Acarol.*, 4: 53–62.

In order to evaluate the effect of continuous, thorough vacuuming on house dust organisms and mite allergen, a cotton carpet was vacuumed every other day, six times in total. Seven weeks later, the carpet was cleaned by means of spray extraction. Samples were taken before and after this wet cleaning.

In total 1150 g of dust was collected, containing approximately 174 000 arthropods (dead and alive) and 9000×10^6 fungal spores. In the course of the experiment, the amount of dust collected at each vacuuming decreased. The number of extracted house dust mites did not decrease significantly, but that of the predator mite *Cheyletus* did. The number of extracted fungal spores showed a significant decrease (from 142 to 16×10^6 spores/m² per minute vacuuming), as did the extracted mite allergen per m². After 7 weeks the number of mite eggs and complete house dust mites had increased enormously. After cleaning by spray extraction another increase in the number of complete mites and mite eggs was found, while the amount of mite allergen was diminished.

The population growth of the house dust mite between the 6th and the 7th vacuuming is probably due to the decrease of their most important predator, *Cheyletus*. After the wet cleaning a number of extra eggs hatched, probably due to the high humidity in the carpet. The procedures used in this study to combat house dust mites may have an adverse effect in the long run.

INTRODUCTION

House dust mites and fungi are important allergen producers in house dust (Alani and Haarlov, 1972; Salvaggio and Aukrust, 1981, Van Bronswijk, 1981; Mosbech, 1985). Patients sensitive to these allergens may respond with asthmatic symptoms, rhinitis, atopic dermatitis or with urticaria from exposure to these substances (Mosbech, 1985). Such patients should avoid inhalation of these allergens. The allergen itself and the allergen producers need to be re-

duced in the person's living and working environment. The right type of furniture and floorcovering should be applied (Van Bronswijk et al., 1985). The most important biotopes for the house dust organisms are the bed, stuffed furniture and the carpet (Lang and Mulla, 1978; Van Bronswijk, 1981; Arlian et al., 1982; Hoffmann, 1982).

One of the possible ways to combat these organisms is by vacuum cleaning. The effectiveness of a vacuum cleaner in reducing house dust mites has been studied by several authors. Massey and Massey (1984) were able to reduce the mites in a mattress and a rug in this way. Mulla et al. (1975) removed 4.5–9.0% of the mites in a mattress by four successive vacuumings. This kind of reduction, however, does not seem to be beneficial to the asthmatic patient (Carswell et al., 1982). The vacuum cleaner itself may also produce a lot of airborne dust (and allergens; Sly et al., 1985). Arlian et al. (1982) were not able to decrease mite numbers in carpets by vacuuming. Van Bronswijk (1985) vacuumed a synthetic carpet for 42 min/m². After this operation, 11% of the mites were still present in the carpet. Wet cleaning or one thorough vacuuming does not reduce mite or fungal quantities in the long run (J.E.M.H. van Bronswijk, personal communication, 1987). The effect of thorough vacuuming on mite numbers over a longer period is as yet unknown.

House dust contains both arthropods and fungi. The fungi are closely associated with the house-dust mite (Sinha et al., 1970; Van Bronswijk and Sinha, 1973; Van de Lustgraaf, 1978; Andersen, 1985). A fungicide interferes with this close association and therefore affects the mites too (De Saint Georges-Gridelet, 1981). It is even possible to reduce asthmatic symptoms by using a fungicide (Van de Maele, 1983).

The aim of this study is to evaluate the effects of wet cleaning and regular, thorough vacuum cleaning on fungal spore numbers, on the number of arthropods living in house dust and on the presence of mite allergen.

MATERIALS AND METHODS

A cotton carpet in the living room (ground floor) of a home in Laren (The Netherlands) was vacuumed for 1 min/m² on 25, 27, 29 and 31 March and on 2 and 4 April, 1985. A Hoover type S2222 with a flexible hose and a small nozzle (Hoover type A) was used. After each vacuuming the paper dust-bag was taken out and brought to the laboratory for analysis.

The carpet had been in use for five successive years. The room sampled was heated by a gas stove without a thermostat. The area vacuumed was 20 m², being nearly the whole area of the carpet: 1 m² was left undisturbed because of a heavy cupboard (mainly containing crockery) standing on the floor. Two upholstered sofas and a stuffed chair were present in the room. The carpet had looped piles (5 mm high) and a foam back and lay upon a wooden floor. Between the floor and the ground underneath there was a space of 50 cm. The

house was approximately 100 years old and was built on sand. During the sampling period the floor was not cleaned in any way.

On 25 May, 7 weeks after the last vacuuming, a sample was taken by vacuuming for 1 min/m². The next day the floor was wet-cleaned by means of the spray extraction method using a "Carpet lover U5" (manufactured by Unisteam Industries, The Netherlands). The entire floor was treated (except the area underneath the cupboard). The carpet was sprayed with a total of 55 l of water, to which 2 l of the detergent "Uniclean grandioos" (Unisteam Industries) had been added. A total of 24 l was extracted afterwards; 33 l of the solution remained in the carpet. Three days after this treatment another sample was taken (vacuuming 1 min/m²). Normal household vacuuming (twice a week) took place between the 6th and the 7th sampling.

Each time before the carpet was vacuumed, the temperature and the relative humidity were measured at twelve different locations on the carpet. A Rotronic Hygroscope BT with a sensor type RA-ST (Rotronic Zürich, Switzerland) was used for this purpose. The temperature and relative humidity of the room were recorded with a thermohygrograph (Dr. Freidrichs Gruppe, 6980 Wertheim, West Germany).

In the laboratory the material from the dust bags was separated into a light, filamental fraction and a heavy, sandy fraction. Mite numbers and fungal spore numbers were assessed in both fractions. In this way the analysis is more reliable (D.P.J. Wassenaar, unpublished results).

The number of xerophilic fungal spores was assessed according to Van Bronswijk (1981). Malt agar plates with a water activity of 0.82 were used to rear the xerophilic fungi. Subsamples of 0.2 g of dust were taken in duplicate from each fraction of every sample and mixed with 5 ml of 50% saccharose. The mixtures were shaken for 10 min using a shaker apparatus and diluted 8, 64 and 512 times. From every dilution 0.1 ml was taken for grafting onto the agar plates. After 3 weeks of incubation at room temperature, the thalli were counted and the fungi were determined according to Onions et al. (1981).

The flotation method (Van Bronswijk, 1981) was used to extract the arthropods from the dust. With this method, four subsamples of 0.5 g each (two subsamples per fraction) were analyzed. To fix the preparation the mites were embedded in Hoyer's medium and heated for 24 h at 60°C. A phase microscope was used to determine the different species and developmental stages. Distinction was made between complete mites (probably alive or recently dead at the time of sampling) and damaged mites (dead at the time of sampling or damaged by the process of vacuuming).

The guanine content was determined in the heavy sandy fraction only. An "Acarex-test für allergenhaltigen Hausstaub" (distributed by HAL-Allergie GMBH, Düsseldorf, West Germany) was used to measure the guanine content. This guanine is present in the faeces of the mites. It can be used as an index for the occurrence of mites (Bischoff and Schirmacher, 1984, 1985; Bischoff

et al., 1985). The guanine values obtained were transformed to mg guanine/g dust (0=0.0 mg; $\frac{1}{2}$ =0.3 mg; 1=0.6 mg; $1\frac{1}{2}$ =1.2 mg; 2=2.5 mg; $2\frac{1}{2}$ =5.0 mg; 3=10.0 mg; in this calculation 0=without guanine; 1=light; 2=medium; 3=strongly positive).

Dust vacuumed by the inhabitants of the house using their own vacuum cleaner was collected too. These samples were weighed but no further analyses were carried out on this dust.

The Kendall correlation test and the inversion test of Wilcoxon were applied for the statistical analysis. A confidence interval of 5% was allowed (Zijp, 1974). All data were stored in a computerized database, using dBASE II (Ashton tate) as a database management system.

RESULTS

A total 1150 g of dust, containing approximately 174 000 arthropods and 9000×10^6 fungal spores, was collected. During the first six vacuumings, the weight of the extracted dust decreased from 257.5 g to 87.0 g. After 7 weeks of non-sampling, the weight of the extracted dust was 116 g. Another 61 g of dust was collected after spray extraction (Fig. 1). Normal household vacuuming of the carpet resulted in the extraction of 31.5 g dust per vacuuming. The amount of dust extracted in the six vacuumings of the experiment was 8.4 times larger than that extracted by the inhabitants in a comparable period of 11 days.

All numbers of arthropods and fungal spores have been transformed to numbers per m² and per min vacuuming. The arthropod most frequently found was *Dermatophagoides pteronyssinus* (Trouessart, 1897), the typical house-dust mite. Except for the sample taken on 28 May, the number of damaged house-dust mites exceeded the number of complete ones. Almost all the *Cheyletus* mites appeared to be damaged. Damaged as well as complete Glycyphaginae were found in various numbers. Most of the complete Glycyphaginae were hypopi. In the first six samples the number of damaged *D. pteronyssinus* increased, after which the numbers decreased; this decrease was not significant ($S=3$). The numbers of *Cheyletus*, however, showed a significant decrease ($S=11$). Seven weeks after the 6th sampling the number of complete mites and mite eggs had increased drastically. This increase of complete mites appeared to be due to an increased number of adults and larvae. Most of the eggs found were probably laid by *D. pteronyssinus* females. *Cheyletus* numbers did not increase during these 7 weeks. After the wet cleaning, only a few damaged house-dust mites could still be extracted. However, the number of complete *D. pteronyssinus* and the number of mite eggs increased (Fig. 2), the increase in complete *D. pteronyssinus* being due to an increase in number of larvae. Besides the mites mentioned in Fig. 2, other arthropods were found in low numbers: *D. farinae* group, *Gohieria fusca*, *Euroglyphus maynei*, *Caloglyphus berlesei*,

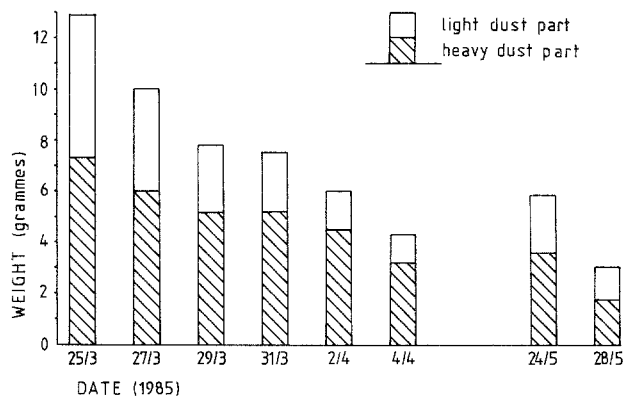


Fig. 1. Quantities of dust extracted from a cotton carpet by vacuuming. The weights are converted to numbers per m² per minute vacuuming. On 25 May 1985 the carpet was wet-cleaned by spray extraction.

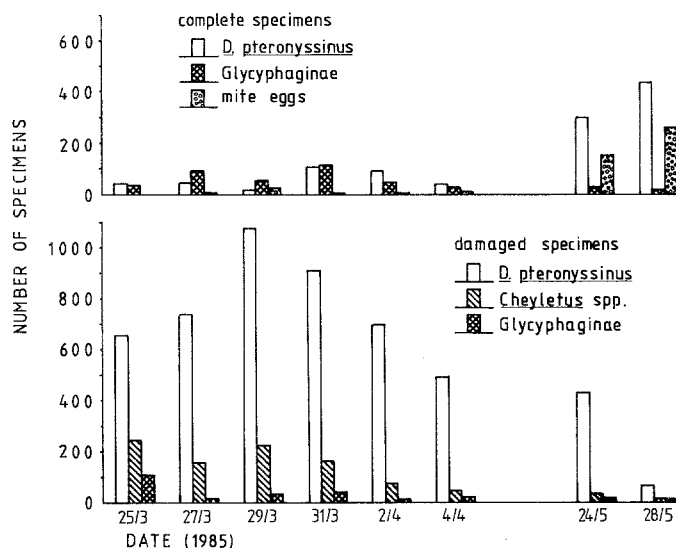


Fig. 2. Numbers of arthropods extracted from a cotton carpet by vacuuming. The numbers are converted to numbers per m² per min vacuuming. On 25 May 1985 the carpet was wet-cleaned by spray extraction.

Demodex sp., Mesostigmata, Tarsonemini, Tydeidae, Cryptostigmata, Psocoptera, a Siphonaptera egg and Thysanoptera.

The number of extracted fungal spores declined significantly ($S=13$), from 144 to 11×10^6 , in the first six samples. Between the 6th and the 7th sampling spore numbers did not increase, but actually decreased further. The wet cleaning did not reduce the amount of fungal spores: in fact, the number of extracted spores rose after the spray extraction (Fig. 3). The spores belonged mainly to

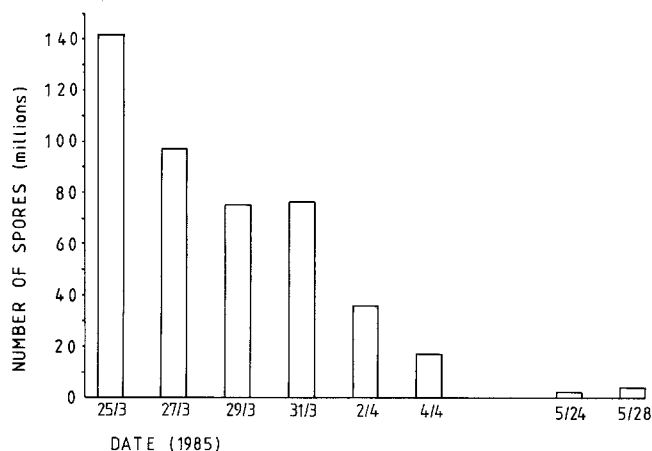


Fig. 3. Numbers of fungal spores extracted from a cotton carpet by vacuuming. The numbers are converted to numbers per m² per min vacuuming. On 25 May 1985 the carpet was wet-cleaned by spray extraction.

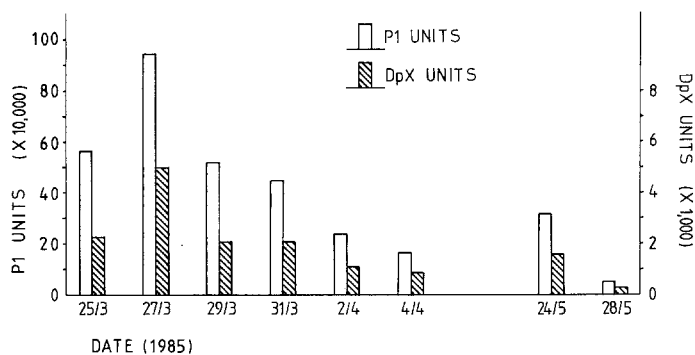


Fig. 4. Numbers of mite antigen units, assessed by means of the RAST-inhibition test, extracted from a cotton carpet by vacuuming. The numbers are converted to numbers per m² per min vacuuming. On 25 May 1985 the carpet was wet-cleaned by spray extraction.

the following groups: *Aspergillus glaucus*, *Pennicillium brevi-compactum* and *Wallemia sebi*.

The mean guanine value was 0.9 mg/g dust (± 0.3). There was no correlation between guanine values and the total number of mites collected ($S=13$).

During the six samplings the quantity of extracted P1-antigen per m² showed a significant decline (Fig. 4; $S=13$). There was a significant correlation between the quantity of guanine and the antigen (P1 and DpX) found in the dust samples ($S=22$ and $S=20$, respectively).

The mean temperature and mean relative humidity of the carpet were 18.1°C (± 1.7) and 60.6% (± 8.5) respectively. The highest relative humidity was recorded during the 8th sampling, 4 days after spray extraction. Probably the carpet was not completely dry at that time. During the experiment, the mean

temperature and mean relative humidity of the room were 17.9°C (± 2.2) and 59.0% (± 7.5) respectively. The larger range of temperatures and relative humidities in the room is partly due to the fact that the heating was turned off during the night.

DISCUSSION

Several methods have been suggested to reduce the number of mites and fungi in the home (Van Bronswijk et al., 1985). A number of investigators have tried to reduce mite numbers by vacuuming, by wet cleaning or by shampooing (Mulla et al., 1975; Arlian et al., 1982; Carswell et al., 1982; Massey and Massey, 1984; Van Bronswijk, 1985). These investigations show that this type of cleaning is not beneficial for the patient with Chronic Obstructive Lung Disease. House-dust fungi were not included in most of these studies. Since there are strong indications of a close association between mites and fungi (Van Bronswijk and Sinha, 1973; Van de Lustgraaf, 1978; De Saint Georges-Grèdelet, 1981), this last group should not be excluded. In our experiment the fungus population was reduced considerably (from 142.2 to 17.3×10^6 spores/ m^2 per minute of vacuum cleaning). The number of extracted complete (living) mites was not reduced after six thorough vacuumings. It seems that only a small percentage of the population was removed during every vacuuming because mites are very hard to extract by this method (Van Bronswijk, 1985). After 7 weeks of non-sampling the number of complete (living) mite adults and larvae and mite eggs had increased by 8 and 21 times respectively. The fungi spore numbers, however, were still low, even lower than before the 7 weeks of non-sampling. This decrease in numbers of fungal spores does not seem to have any influence on the mite numbers.

The increase in extracted complete mites found on 24 May (see Fig. 2) may have been caused by a recolonization by mites inhabiting the upholstered furniture. A seasonal effect is not likely to be the cause of this rise in numbers. The climatic conditions inside the room did not improve until after 8 May (above 60% relative humidity). However, a small peak in the spring has been reported in other studies (Hughes and Maunsel, 1973; Van Bronswijk, 1973; Popescu and Banescu, 1975). In this experiment the removal of the mites' most important predator, *Cheyletus*, is more likely to be the cause of the enormous population growth. This hypothesis is supported by the findings of several authors who observed a control of prey mites by *Cheyletus*. In some cases 100% success in exterminating prey was achieved by using *Cheyletus* (Siggaard, 1921; Solomon, 1946; Norris, 1958; Pulan and Verner, 1965; Van Bronswijk et al., 1971). Van Bronswijk et al. (1971) also explained the occurrence of higher numbers of house-dust mites in more thoroughly cleaned rooms by the removal of their predator. In this experiment, the immature stages of *D. pteronyssinus* developed into adults between the 6th and the 7th sampling.

Population growth was mainly caused by an increase in numbers of adults (from 2 per m²/min at the 6th sampling to 202 per m²/min at the 7th sampling) and larvae (from 6 per m²/min at the 6th sampling to 65 per m²/min at the 7th sampling). Because the adults live longer than the immature stages (Van Bronswijk, 1981), their number should be higher. During the first six samplings, however, the number of nymphs exceeded the number of larvae and adults significantly ($U=36$ and $U=34$ respectively). At the start of this study there was apparently an undisturbed equilibrium between predator and prey, in which only a few of the nymphs may have reached maturity. At the end of the study the immature stages had all reached maturity, due to a decrease in predator numbers and the hatching of recently laid eggs.

The fact that the *Cheyletus* specimens were mostly damaged does not mean that these mites were dead at the time of sampling. They can be damaged easily by the process of vacuuming (J.E.M.H. van Bronswijk, personal communication, 1986). The manner of locomotion and the feeding habits, for example, of predator mites are different from that of their prey. Due to these differences in biology the predator mite may be extracted more easily by a vacuum cleaner.

The quantity of extracted dust decreased during the first six samplings. It is to be expected that passive substances present in the dust show the same pattern of reduction. This applies to the extracted P1 and DpX mite antigen units, to the extracted fungal spores, and to the extracted damaged arthropods ($S=24$, $S=22$, $S=22$ and $S=18$ respectively). The vacuum cleaner collected less dust after than just before the wet cleaning. J.E.M.H. van Bronswijk (personal communication, 1987) extracted more dust after the wet cleaning, hypothesizing that the greasy substances in the carpet (which hold the dust together) are dissolved by the detergent used. We also used a detergent, but the carpet did not seem to be completely dry during the 8th vacuuming. This could explain the different findings. The number of extracted complete *D. pteronyssinus* and mite eggs had increased after the spray extraction. This rise in complete mite numbers was in the number of larvae (from 65 to 202 per m²/min). The humid conditions in the carpet, caused by the wet cleaning, probably gave rise to accelerated egg hatching and egg laying. The number of damaged *D. pteronyssinus* specimens collected was reduced drastically after this wet cleaning, supporting the hypothesis that the living mites clasp themselves to the carpet fibres, which prevents them from being sucked away (and, consequently, damaged).

It should be noted that by using the flotation method only 15–20% of the arthropods present in house-dust can be found (Van Bronswijk, 1981). In other words, the actual number of mite present is much higher.

In conclusion we can say that spray extraction and thorough vacuuming do not reduce the mite population. In the long run, thorough vacuuming may even increase mite numbers by reducing predator numbers. Wet cleaning may improve the microclimatic conditions in such a way that mite eggs hatch more

rapidly. The use of these cleaning methods in the combat against house-dust mites is inadvisable.

ACKNOWLEDGEMENTS

We would like to thank Dr. J.E.M.H. van Bronswijk and several colleagues for their critical remarks, Drs. A.M. Iken for correcting the English text, Mrs. J. van Leeuwen for carrying out the RAST inhibition tests and the Dutch Asthma Foundation for awarding a research grant.

REFERENCES

- Alani, M.D. and Haarlov, N., 1972. The house-dust mite: a possible source of allergen in the environment of patients with atopic dermatitis. *J. Natl. Med. Assoc.*, 64: 302-304.
- Andersen, A., 1985. Microfungi in beds and their relation to house-dust mites. *Grana*, 24: 55-59.
- Arlian, L.G., Bernstein, I.L. and Gallagher, J.S., 1982. The prevalence of house dust mites, *Dermatophagoides* spp., and associated environmental conditions in homes in Ohio. *J. Allergy Clin. Immunol.*, 69 (6): 527-532.
- Bischoff, E. and Schirmacher, W., 1984. Farbnachweis für allergenhaltigen Hausstaub, 1. Mitteilung. *Allergologie*, 7: 446-447.
- Bischoff, E. and Schirmacher, W., 1985. Farbnachweis für allergenhaltigen Hausstaub, 2. Mitteilung: weitere Gesichtspunkte. *Allergologie*, 8: 36-38.
- Bischoff, E., Schirmacher, W. and Schober, G., 1985. Farbnachweis für allergenhaltigen Hausstaub, 3. Mitteilung: Anwendung in der Praxis. *Allergologie*, 8: 97-99.
- Carswell, F., Robinson, D.W., Oliver, J., Clark, J., Robinson, P. and Wadsworth, J., 1982. House dust mites in Bristol. *Clin. Allergy*, 12: 533-545.
- De Saint Georges-Gridelet, D., 1981. Mise au point d'une stratégie de controle de l'acarien des poussières (*Dermatophagoides pteronyssinus*) par utilisation d'un fongicide. *Acta Oecol. Oecol. Appl.*, 2 (2): 117-126.
- Hoffmann, G., 1982. Hausstaubmilben als Krankheitserreger beim Menschen. *Schriftenr. Ver. Wasser Boden Lufthyg.*, 53: 385-401.
- Hughes, A.M. and Maunsel, K., 1973. A study of a population of house dust mites in its natural environment. *Clin. Allergy*, 3: 127-131.
- Lang, J.D. and Mulla, M.S., 1978. Spatial distribution and abundance of house dust mites, *Dermatophagoides* spp., in homes of southern California USA. *Environ. Entomol.*, 7 (1): 121-127.
- Massey, J.E. and Massey, D.G., 1984. Effect of vacuum cleaning on house dust mites. *Hawaii Med. J.*, 43 (11): 404-406.
- Mosbech, H., 1985. House-dust mite allergy. *Allergy*, 40: 81-91.
- Mulla, M.S., Markrider, J.R., Galant, S.P. and Amin, L., 1975. Some house dust control measures and abundance of *Dermatophagoides* mites in southern California (Acari: Pyroglyphidae). *J. Med. Entomol.*, 12: 5-9.
- Norris, J.D., 1958. Observations on the control of mite infestations in stored wheat by *Cheyletus* spp. (Acarine, Cheyletidae). *Ann. Appl. Biol.*, 46 (3): 411-422.
- Onions, A.H.S., Allsopp, D. and Eggings, H.O.W. (Editors), 1981. *Smith's Introduction to Industrial Mycology*. Edward Arnold, London, 398 pp.
- Popescu, I.G. and Banescu, O., 1975. Presence of *Dermatophagoides pteronyssinus* in the houses of asthmatics sensitized to house dust. A 1 year study. *Rev. Roum. Med. Interne*, 13 (4): 293-295.

- Pulpan, J. and Verner, P.H., 1965. Control of Tyroglyphoid mites in stored grain by the predatory mite *Cheyletus eriditus* (Schrank). *Can. J. Zool.*, 43(3): 417-432.
- Slavaggio, J. and Aukrust, L., 1981. Mold-induced asthma. *J. Allergy Clin. Immunol.*, 68: 327-346.
- Siggaard, N., 1921. On seed mites and measures against them. *Rev. Appl. Entomol.*, 9: 362 (English abstr.).
- Sinha, R.N., Van Bronswijk, J.E.M.H. and Wallace, H.A.H., 1970. House dust allergy, mites and their fungal associations. *Can. Med. Assoc. J.*, 103: 300-301.
- Sly, R.M., Josephs, S.H. and Eby, D.M., 1985. Dissemination of dust by central and portable vacuum cleaners. *Ann. Allergy*, 54: 209-212.
- Solomon, M.E., 1946. Tyroglyphid mites in stored products. *Ecological studies. Ann. Appl. Biol.*, 33: 82-97.
- Van Bronswijk, J.E.M.H., 1973. *Dermatophagoides pteronyssinus* (Trouessart:1897) in mattress and floor dust in a temperate climate (Acari: Pyroglyphidae). *J. Med. Entomol.*, 10: 63-70.
- Van Bronswijk, J.E.M.H. (Editor), 1981. *House Dust Biology for Allergists, Acarologists and Mycologists*. NIB Publishers, Zeist, The Netherlands, 316 pp.
- Van Bronswijk, J.E.M.H., 1985. The effectiveness of a vacuum cleaner in removing dust, mites and possibly mite allergens from a carpet. *Airways*, 4(2): 10-16 (in Dutch).
- Van Bronswijk, J.E.M.H. and Sinha, R.N., 1973. Role of fungi in the survival of *Dermatophagoides* (Acarina: Pyroglyphidae) in house dust environment. *Environ. Entomol.*, 2: 142-145.
- Van Bronswijk, J.E.M.H., Schoonen, J.M.C.P., Berlie, M.A.F. and Lukoschus, F.S., 1971. On the abundance of *Dermatophagoides pteronyssinus* (Trouessart, 1897) (Pyroglyphidae: Acarina) in house dust. *Res. Popul. Ecol.*, 13: 67-79.
- Van Bronswijk, J.E.M.H., Kniest, F.M., Schober, G., Elixmann, J.H., Wassenaar, D.P.J., De Saint Georges-Grédelet, D. and Lange, B., 1985. Dwelling hygiene and COLD, background information and advice for the patient in Benelux and West Germany. *Contrastma* (Dutch Asthma Foundation), 24(4): 1-28; 25(1): 1-24 (in Dutch).
- Van de Lustgraaf, B., 1978. Ecological relationships between xerophilic fungi and house dust mites (Acarida: Pyroglyphidae). *Oecologia* (Berlin), 33(3): 351-360.
- Van de Maele, B., 1983. A new strategy in the control of house dust mite allergy. *Pharmatherapeutica*, 3(7): 441-444.
- Zijp, W.L. (Editor), 1974. *Handbook of Statistical Tests*. H.D. Tjeenk-Willink, Groningen, The Netherlands, 283 pp. (in Dutch).