

Dust from carpeted and smooth floors

IV. Solid material, proteins and allergens collected in the different filter stages of vacuum cleaners after ten days of use in schools.

T. DYBENDAL, W. C. WEDBERG* & S. ELSAYED

Allergy Research Group, Laboratory of Clinical Biochemistry, University Hospital, Haukeland sykehus and *Indoor Environment Laboratory, University of Bergen, Norway

The accumulation of dust, proteins and allergens from alder, birch, timothy, cat, dog, mite, hen egg white, codfish and mould in schools was investigated by analysing the content of vacuum cleaners after 10 days of use. The main goals were to compare the dust accumulation on carpeted and smooth floors and to estimate to what degree the three vacuum cleaner filter stages (i.e. the disposable bag, the main filter and the microfilter) collected dust, proteins and allergens. Carpeted floors accumulated more dust, proteins and allergens per unit area than smooth floors. Histamine release studies of some of the dust extracts showed that the dust from carpeted floors released histamine from passively sensitized basophils at concentrations for which dust from smooth floors gave low or no histamine release. The analyses showed that most of the dust, proteins and allergens were retained in the dust bags. Less than 1% of the vacuumed material had accumulated in the main filters, which, according to the manufacturer, detain 99.5% of particles $> 2 \mu\text{m}$. By the use of a scanning electron microscope (SEM), particle deposits were observed in the microfilters. These deposits, which represented $< 0.1\%$ of the total mass, showed no significant allergenic activity. Thus, for the field conditions of this study, the microfilters were not needed for cleaning the exit air of allergens, although they were useful for removing fine ($< 2 \mu\text{m}$) particles.

Key words: allergens; carpeted floors; dust; vacuum cleaners.

Accepted for publication 6 December 1990

CLINICAL ASPECTS

Carpeted floors accumulated more dust, proteins and allergens per unit area than smooth floors. Allergens included in dust from carpeted floors released histamine from passively sensitized basophils at concentrations for which dust from smooth floors gave low or no histamine release. Most of the dust and allergens were collected in the dust bags during vacuuming. Less than 1% of the total vacuumed material passed through the dust bags further to the main and microfilters during vacuuming. The allergenic activities of dust from the main filter were low, even after removal of molecules with $M_r < 3500$ daltons by dialysis. By scanning electron microscopy we could clearly observe particle deposits in the third and final filter stage, the microfilter. These deposits showed little or no allergenic activity.

The cleaning efficiency of commercial vacuum cleaners will usually differ from model to model. Vacuum cleaning of carpets can in-

crease the number of airborne particles of diameters $> 0.5 \mu\text{m}$ (10). Thus, the paper bag used in vacuum cleaners without subsequent

filter systems may serve to redisperse parts of the collected dust, creating a more particle and allergen polluted environment after vacuuming.

We have previously investigated the occurrence of antigens and allergens in dust samples from carpeted and smooth floors in a series of schools (1, 2). In this follow-up study we make a detailed comparison of dust accumulations on carpeted and smooth floors using a specific, high quality brand of vacuum cleaner. We also investigate to what extent dust and allergens are retained by each of several filter stages of this vacuum cleaner. Thus, all schools participating in the study were provided with identical vacuum cleaners having three filter stages: (1) a double-walled, disposable dust bag, (2) a main filter of cotton and (3) a final microfilter for removing fine particles. Aside from determining the allergen content of the bulk of the collected material, we aim to establish the usefulness of the final microfilter in removing allergens from the exit air.

MATERIAL AND METHODS

Nilfisk GS 90 vacuum cleaners (Fisker and Nielsen A/S, Denmark) were distributed to each of the 10 schools participating in the investigation. This vacuum cleaner is supplied with a double disposable filter bag (Nilfisk double filter bag, ref. No.816200), a main filter of cotton (Nilfisk main filter) and a microfilter of polypropylene and polycarbonate fibres (Nilfisk Micro-static filter, ref. No.116410). The cotton filter is impregnated with a mixture of stearin, paraffin oil and the water soluble substances propyl p-oxybenzoate, methyl p-oxybenzoate, triethanol amine and sodium hexametaphosphate. The microfilter has a three-layer structure, with one layer of fine fibres (of diameters 2–5 μm) sandwiched between two layers of coarse fibres (diameters 20–50 μm). The filter has a total thickness of about 3 mm. According to the manufacturer, the microfilter contains fibres carrying an electric charge (presumably of the electret type). The vacuum cleaner construction is such that only a small percentage of the microfilter area

is exposed to the exit air. According to the manufacturer, the main filter retains 99.5% of particles > 2 μm , whereas the microfilter retains 99% of particles > 0.7 μm , 95% of particles > 0.3 μm and 90% of particles > 0.2 μm .

For sample collection 10 schools with both carpeted and smooth floors were chosen. In each school dust samples were collected from one classroom with carpeted floor and one classroom with smooth floor. Classrooms used for the same number of hours per week (22 h on the average) and for the same function were chosen. The whole floor area was vacuumed thoroughly daily after school hours for 2 weeks (10 schooldays) during February 1989. The dust bags, main filters and microfilters were packed in clean plastic bags and mailed to the laboratory at the end of the 10-day sampling period. The samples were kept at 0°C until extracted.

The content of the vacuum cleaner bags was weighed and the coarse constituents (sand, paper clips, etc.) separated from the dust. The dust was extracted in 50 mM NH_4HCO_3 , 1:10 (w/v) under gently shaking for 20 h at 4°C. The dust extracts were filtered (Schleicher & Schüll folded filters, Dassel, Germany), centrifuged (6000 rpm, Beckman model J-21B centrifuge, 4°C, 45 min), refiltered and lyophilised. The lyophilised extracts were kept at -70°C until analysed. Samples corresponding to the amount of lyophilised material from 1 m² floor area were prepared for the testing of allergenic activity. The main filters were cut in pieces and extracted in 50 mM NH_4HCO_3 , 700 ml, containing 0.002% (v/v) Tween, for 20 h. The extracts were filtered, centrifuged (6000 rpm, Beckman model J-21B centrifuge, 4°C, 45 min) and lyophilised. Solutions of main filter extracts of 50 mg/ml were prepared for further testing. The microfilters were extracted in 200 ml of the buffer described above. The extracts were filtered, lyophilised and reconstituted in 2 ml distilled water. The solution was centrifuged (2000 g), and the supernatant was used in further analyses.

Two unused main filters and two unused microfilters were extracted under the same

conditions as the sample filters in order to adjust for background contributions from the filters themselves. A series of 10 unused main filters and microfilters were weighed in order to establish the average weight.

Protein analysis. The protein contents of lyophilised extracts of dust samples, main filters and microfilters were determined by the Lowry method (7), using bovine serum albumin as standard.

Allergens. Crude birch and alder pollen extracts, hen egg white extract and partially purified codfish allergen extract were prepared as described previously (3, 4, 5, 11).

Human sera. The pooled human sera from patients with Type I allergy used in this investigation have been described previously (2).

Allergen discs of birch, alder, hen egg white and codfish were prepared as described previously (2). Other paper discs (mould, cat and dog dander, timothy and mite) were purchased from Pharmacia AB, Uppsala, Sweden.

Specific IgE inhibition tests

The radio allergosorbent test (RAST) inhibition assays were performed as described previously (1, 2). The 50% inhibitions could not be deter-

mined due to low concentrations and great variations in contents of alder, birch and timothy pollen, mite and food allergens in the extracts. Solutions corresponding to lyophilised material from 1 m² floor area were therefore compared directly. Crude and dialysed extracts of main filters were analysed in concentrations of 50 mg/ml. Lyophilised extracts of microstatic filters were diluted to a total volume of 2 ml, and 100 µl of this solution was tested in each parallel. Briefly, an aliquot of 50 µl patient serum pool was added to 100 µl dust or filter extract and incubated for 1 h at room temperature. An allergen disc coated with the appropriate allergen was added to the mixture and incubated for 3 h. The disc was further incubated overnight with 50 µl ¹²⁵I-anti-IgE (Phadebas RAST isotope, Pharmacia AB, Uppsala, Sweden). The tests were performed in duplicate. Crude and dialysed extracts of unexposed filters were used as controls, and the IgE-inhibition backgrounds were subtracted from the sample results.

Dialysis

Solutions of parts of the lyophilised material from dust samples and main filters underwent

Table 1.

Total vacuumed material, dust, crude and dialysed extracts, and protein in three filter stages (dust bags, main filters and microfilters) of vacuum cleaners after 10 days of sampling. All values are in mg/m² of floor area. Arithmetic mean and standard deviation are given.

	Carpeted floors (n = 10)	Smooth floors (n = 10)	P values
Dust bags			
vacuumed material	6350±4418	3480±2320	0.007
dust	2830±1763	680±355	0.001
crude extract	146±95	32±21	0.001
protein (crude extract)	11±7	2±1	0.001
dialysed extract, (M _r > 3.500)	35±22	7±5	0.004
Main filters			
dust	<20	<30	n.a.
dialysed extract, (M _r > 3.500)	0.5±0.6	0.3±0.4	0.003
protein (dialysed extract)	0.06±0.09	0.02±0.03	0.014
Microfilters			
dust	<2	<2	n.a.
protein (crude extract)	<0.001	<0.001	n.a.

The Wilcoxon matched-pairs test was used to compare the various parameters in samples from 10 carpeted and 10 smooth floors. n.a. = not applicable

Table 2.

The allergenic activity, expressed as percent specific IgE inhibition, in solutions of dust samples corresponding to dust from 1 m² carpeted and smooth floors. Arithmetic mean, standard deviation and range for samples from 10 different schools are given. With the exception of timothy, the differences between carpeted and smooth floors were significant ($P < 0.05$)

	Carpeted floors (n = 10)	Smooth floors (n = 10)	P values
Alder	20±15 (0-48)	5±7 (0-16)	0.007
Birch	16±12 (0-40)	3±4 (0-12)	0.001
Timothy	13±11 (0-27)	7±6 (0-20)	0.053
Cat	73±9 (62-85)	44±13 (26-68)	0.002
Dog	84±11 (62-95)	54±18 (24-76)	0.002
Mite	31±17 (11-59)	9±12 (0-40)	0.010
Egg white	33±8 (17-44)	16±10 (2-34)	0.005
Codfish	37±11 (19-53)	9±11 (0-25)	0.001
Mould	85±8 (69-95)	59±20 (29-84)	0.001

intensive dialysis (membrane cut off 3500 daltons) in 5×10^{-4} M NH_4HCO_3 . The dialysed extracts were lyophilised and stored at -73°C . The total amount of dialysed material with molecular weight > 3500 daltons was calculated for each dust and filter extract.

Leukocyte separation, lactic acid stripping and passive sensitization

Peripheral blood from normal donors was obtained by venipuncture after informed consent. 30 ml blood was mixed with 7.5 ml 6% Dextran 70 in physiological saline, 225 mg

released histamine, %

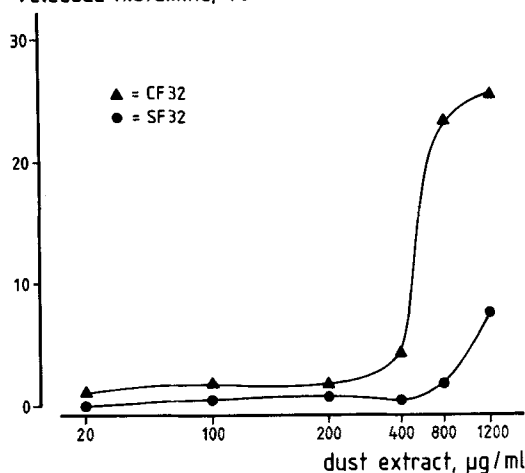


Fig. 1. Histamine release (%) induced by dust extracts from a carpeted (CF 32) and a smooth floor (SF 32) in lactic acid stripped leukocytes sensitized with serum from allergic patient K.S. (RAST class: dust 3, birch 4, mite 3-4, cat 1).

dextrose and 3 ml 0.1 M ethylene diamine tetraacetic acid (EDTA, disodium salt), pH 7.6. The erythrocytes were sedimented at room temperature for 90 min. The leukocyte-

released histamine, %

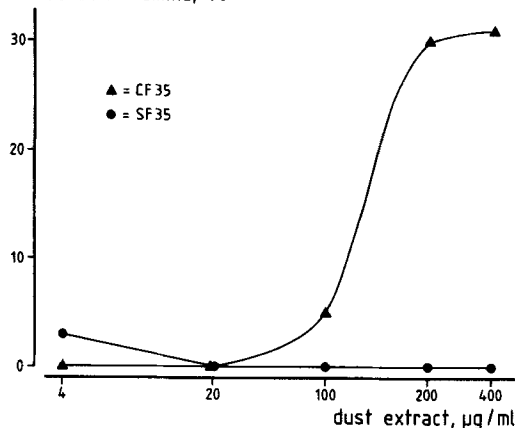


Fig. 2. Histamine release (%) induced by dust extracts from a carpeted (CF 35) and a smooth floor (SF 35) in lactic acid stripped leukocytes sensitized with serum from allergic patient T.H. (RAST class: dust 2-3, cat 3, dog 1, alder 1).

containing plasma was removed and centrifuged (220 *g*, 8 min, 4°C). The sedimented cells were washed twice with PA (PIPES 25 mM, NaCl 110 mM, KCl 5 mM, NaOH 40 mM, HSA 0.03 %, adjusted to pH 7.4), once with PAG (PA with 0.1 % D-glucose) and once with physiological saline. The cells were then resuspended in lactic acid solution (lactic acid 10 mM, NaCl 140 mM, KCl 5 mM), pH 3.9, for 3.5 min according to the procedure of Pruzansky et al. (9). The cells were washed twice with PAG. The sediment was resuspended in PA, and passive sensitization was accomplished by the method of Levy & Osler (6). Sera from patients with IgE against cat, dog and dust (RAST classes 2-3) were used in the sensitization procedures. The mixture was

incubated for 90 min. The cells were washed twice in PA and resuspended in PACM/D₂O (PA with 0.6 mM Ca²⁺, 1.0 mM Mg²⁺ and 50 % deuterium oxide) for histamine release studies.

Histamine release and measurement

Dilutions of sterile filtered dust extracts in PACM/D₂O in the range from 20-1200 µg/ml were added to 400 µl aliquots of leukocyte suspension. A control set of unsensitized basophils was similarly challenged by different concentrations of the extracts. The mixtures were incubated for 60 min at 37°C. The total histamine was released by freezing at -70°C and thawing five times. The samples were centrifuged (600 *g*, 10 min), and the supernatants were analysed for histamine using Pharmacia Histamine Radioimmunoassay (Pharmacia AB, Uppsala, Sweden). An antigen blank was included to correct for a possible content of histamine. Spontaneous release values were subtracted from the corresponding release of the sensitized cells. The mean of duplicate determinations was calculated, and histamine release was expressed as percentage of total cellular histamine.

Scanning electron microscope analysis

Square sections of approximately 10 × 10 mm were cut from the contaminated (discoloured) regions of the microfilters, and the three distinct fibre layers carefully separated using tweezers. The resulting sheets of filter material were affixed to SEM specimen stubs using electrically conductive epoxy. The mounted samples were further prepared for SEM analysis by thoroughly coating them with carbon and gold using standard vacuum evaporation techniques. The samples were analysed in a Philips Model 515 SEM in the secondary electron imaging mode. Due to the complex nature of the filter matrix, low primary electron beam voltages were employed in order to obtain adequate image quality.

Table 3.

Allergenic activities, expressed as specific IgE inhibition percents, in solutions (50 mg/ml) of dialysed (*M_r* > 3500 daltons) main filter extracts after sampling from carpeted and smooth floors. Arithmetic mean, standard deviation and range are given. Significant differences in allergen content in main filters used during sampling of carpeted and smooth floors were found in the case of alder, birch and cat

	Carpeted floors (<i>n</i> = 10)	Smooth floors (<i>n</i> = 10)	<i>P</i> values
Alder	7±7 (0-18)	5±5 (0-15)	0.032
Birch	3±4 (0-12)	1±1 (0-3)	0.042
Timothy	0	0	0.500
Cat	7±7 (0-18)	2±3 (0-9)	0.003
Dog	9±4 (2-15)	6±4 (0-13)	0.097
Mite	11±4 (4-18)	8±5 (0-16)	0.097
Egg white	4±3 (1-9)	3±2 (0-7)	0.423
Codfish	0	0	0.500
Mould	4±2 (0-6)	4±2 (0-7)	0.423

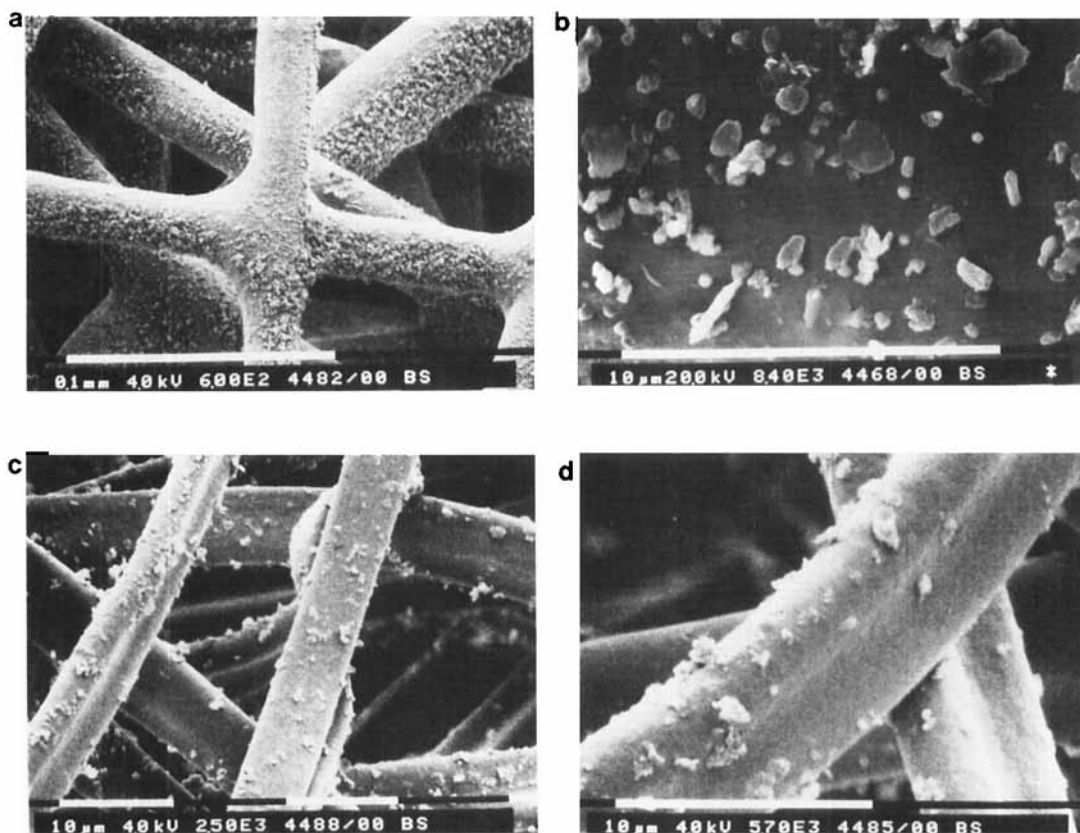


Fig. 3. Scanning electron micrographs of microfilter dust deposits. Deposits in the coarse fibre region at original magnifications 600 $\times$ (a) and 8400 $\times$ (b). Deposits in the fine fibre region at original magnifications 2500 $\times$ (c) and 5700 $\times$ (d).

Statistics

The Wilcoxon matched-pairs test was used to compare the various results of the analyses of the dust from carpeted and smooth floors. The limit of significance chosen was 0.05.

RESULTS

The amount of material collected in the various filter stages in mg/m² floor area is shown in Table 1. Most of the vacuumed material (> 99%) was retained in the dust bags. The weight of dust deposited in the main filters and microfilter represented < 1% and 0.1%, respectively, of the total vacuumed material. Carpeted floors contained more coarse material,

dust, lyophilised extract and protein per unit area than smooth floors. As shown in Table 1, the differences were highly significant (*P* values 0.001–0.007). We also found a significant difference in the weight and protein content of dialysed main filter extracts. The amount of material after extraction and lyophilisation of the microfilters was minor, and the material was amorphous and adhesive, making it impossible to weigh accurately. The weight of crude extract is therefore not given. The lyophilised extracts were bluish in colour, likely due to the presence of cupric ions. According to the vacuum cleaner manufacturer, the copper may originate from the vacuum cleaner motor. The amount of protein collected by the microfilters was < 1 µg/unit floor area.

The specific IgE inhibition values in solutions of dust from 1 m² carpeted and smooth floors

are shown in Table 2. The content of pollen allergens from alder, birch and timothy was rather low. Allergenic activity of cat, dog and mould was demonstrated for all the samples, and the specific IgE binding inhibition values were high. Food allergens (egg white and cod-fish) were also detected. The higher allergen contents in samples from carpeted floors compared with samples from smooth floors were obvious. With the exception of timothy, these differences were statistically significant. Some of the dust extracts were tested for their ability to induce histamine release from presensitized basophils. Dust from carpeted floors induced histamine release at lower concentrations than dust from smooth floors, thus confirming the higher allergen content in dust from carpeted floors. Examples of histamine release curves are shown in Figs. 1 and 2. As can be seen from the figures, dust extracts from carpeted floors CF32 and CF35 gave about 30% released histamine at concentrations of 1200 µg/ml and 200 µg/ml, respectively, while dust extracts from smooth floors SF32 and SF35 gave low or no histamine release at the same concentrations.

The mean specific IgE inhibition values in solutions of crude main filter extracts varied from 0 to 5% for the allergens tested (results not shown). After dialysis (cut off 3500 daltons) of crude main filter extracts, the amount of material was reduced by about 85% (w/w). Extracts with $M_r > 3500$ daltons showed an increase of the allergenicity compared with the crude extracts. Allergenic activities in solutions of dialysed main filter extracts are shown in Table 3. The amounts of alder, birch and cat allergens were significantly higher in main filters used during sampling of carpets. Dialysed extracts of unexposed main filters showed no detectable RAST inhibition for alder, birch, timothy, cat, mite and food allergens. The only unspecific inhibitions obtained were for dog (7%) and mould (87%); these values were subtracted from the sample results. The high mould inhibition RAST indicated mould contamination in unexposed filters.

By scanning electron microscopy we observed particle deposits in both the coarse and fine fibre regions of the microfilters (Fig. 3). The coarse

fibre deposits were located on one side of the fibres (Fig. 3 a,b). This suggests that the deposition in this region is due to impaction, i.e. that particles are removed from the air stream by inertial forces. In contrast, the fine fibre deposits were evenly distributed around the fibre circumference (Fig. 3 c,d), indicating that the collection mechanism in this region is that of electrostatic precipitation. Large numbers of particles were observed in the contaminated regions of the microfilters. Nevertheless, the total volume, and thus mass, of the dust deposits was judged to be small compared with the volume and mass of the filter itself. For both microfilter regions the maximum observed particle size was about 2 µm. The measured microfilter RAST inhibition values were minor, the mean values being < 3% for all allergens tested (results not shown). No differences could be detected when comparing the two types of floors.

DISCUSSION

In the experimental schedule used, the whole floor area was vacuumed, since vacuuming a part of the whole area in classrooms may not be representative for the rest of the floor. The comparison of carpeted and smooth floors showed a clearly higher content of dust, proteins and allergens in the carpeted floors. On average, four to five times more dust as well as lyophilised extracts and proteins were detected per unit area of carpeted floor. In a previous study (2), the amounts of dust on carpeted and smooth floors were found to be nearly the same. That greater amounts of dust were obtained from carpeted floors in this study may be due to changes in cleaning routines, aging of the carpets, and the use of a different vacuum cleaner model. In three of the 10 schools investigated the ordinary cleaning schedules were changed from daily vacuum cleaning to vacuuming three times a week since our last investigation in 1988 (2). The mean age of the carpets in this investigation was approximately 9 years compared with 5 years in our previous study. The vacuum cleaner used this time may have been more effective in removing dust and dirt from the carpet "reservoir".

As expected on the basis of the difference in dust content, significantly more allergens were present on the carpeted floors. The main allergens detected were cat, dog and mould. The occurrence of cat and dog allergens in places where no cats or dogs are allowed has previously been reported by us and others (1, 2, 8, 12). High birch inhibition RAST values could be associated with schools located in the vicinity of birch forests. Dust from carpeted floors released histamine from sensitized basophils at concentrations for which dust from smooth floors gave low or no histamine release, thus confirming the higher allergen content in dust from carpeted floors.

Most of the vacuumed material was collected in the dust bags. Less than 1% by weight was found in the subsequent filter stages. The larger amounts of dialysed extract and proteins detected in main filters representing carpeted floors are probably due to the larger total amounts of dust collected. The mean allergenic activities in samples of the main filter extracts were low. The individual RAST inhibition values ranged up to 18%, however, demonstrating allergenic activity in a number of samples. These RAST inhibition values confirm allergenic activity in the main filter extracts, bearing in mind that only a part of the total lyophilised material was tested. When comparing main filters representing carpeted and smooth floors, statistically significant differences in allergen content were found only in the case of dialysed extracts, and only for alder, birch and cat allergens.

Extraction and lyophilisation of the microfilters gave small quantities of material. By SEM we could clearly demonstrate the presence of particle deposits in the microfilters. We suggest that substantial proportions of all particle varieties (whether defined by size, shape or composition) that escape the first two filter stages will deposit in the microfilters. Large particles will deposit by impaction, whereas small particles will be collected either by electrostatic or diffusional forces. This view is supported by filter performance tests which, according to the manufacturer, show an efficiency of 99% for 0.7 μm particles and 90% for 0.2 μm particles. It is reasonable to assume, therefore, that the

set of compounds present in the microfilter deposits will be the same as that of the dust exiting the main filters.

The mean percent IgE inhibition for the allergens tested in the microfilters exceeded in no cases 3%, indicating no significant allergenic activity after 10 days of sampling. From this we deduce, that for the particular field conditions of our investigation, the microfilters were not needed for trapping allergens, although the SEM photomicrographs clearly indicated that they were useful for cleaning the exit air of submicron particles. The small increase in weight of the microfilters after 10 days of use concealed a large number of submicron particles, emphasizing the importance of microfilters for decreasing the amount of airborne particles during and after vacuum cleaning.

ACKNOWLEDGEMENTS

This study was supported by the Royal Norwegian Council for Scientific and Industrial Research (NTNF) and the Norwegian Carpet Delivery Organisation. The staff at the following schools are sincerely acknowledged for their kind cooperation: Heer, Sogsti, Seiersten, Drøbak, Storevarden, Tananger, Dysjaland, Stangeland, Haga, and the Red Cross Kindergarten in Stavanger. Mr. Jan K Hebnes at Sola Education office is thanked for his help with arrangement of dust sampling in the five schools in the Stavanger area.

REFERENCES

1. Dybendal T, Hetland T, Vik H, Apold J, Elsayed S. Dust from carpeted and smooth floors. I. Comparative measurements of antigenic and allergenic proteins in dust vacuumed from carpeted and non-carpeted classrooms in Norwegian schools. *Clin Exp Allergy* 19, 217-224, 1989.
2. Dybendal T, Vik H, Elsayed S. Dust from carpeted and smooth floors. II. Antigenic and allergenic content of dust vacuumed from carpeted and smooth floors in schools under routine cleaning schedules. *Allergy* 44, 401-411, 1989.
3. Elsayed S, Aas K. Isolation of purified allergens (cod) by isoelectric focusing. *Int Arch Allergy Appl Immunol* 40, 428-438, 1971.
4. Elsayed S, Hammer ASE, Kalvenes MB, Flørvaag E, Apold J, Vik H. Antigenic and allergenic determinants of ovalbumin. I. Peptide mapping, cleavage of the methionyl peptide bonds and enzymic hydrolysis of native and carboxymethyl OA. *Int Arch Allergy Appl Immunol* 79, 101-107, 1986.
5. Flørvaag E, Elsayed S. Comparative studies on tree pollen allergens. VII. Immunological properties of the

- alder (*Alnus incana*) pollen extracts. *Int Arch Allergy Appl Immunol* 75, 300-308, 1984.
6. Levy DA, Osler AG. Studies on the mechanisms of hypersensitivity phenomena. XIV. Passive sensitization in vitro of human leukocytes to ragweed pollen antigen. *J Immunol* 97, 203-212, 1966.
 7. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurements with the Folin phenol reagent. *J Biol Chem* 193, 265-275, 1951.
 8. Price JA, Reiser J, Longbottom, JL, Warner JO. Inhalant allergy in asthmatic children: skin prick test, radioallergosorbent test and chemiluminescent assay compared with allergen levels in their mattress dusts. *Int Arch Allergy Appl Immunol* 88, 183-184, 1989.
 9. Pruzansky JJ, Grammer LC, Patterson R, Roberts M. Dissociation of IgE from receptors on human basophils. I. Enhanced passive sensitization for histamine release. *J Immunol* 131, 1949-1953, 1983.
 10. Sly RM, Josephs SH, Eby DM. Dissemination of dust by central and portable vacuum cleaners. *Ann Allergy* 54, 209-212, 1985.
 11. Vik H, Elsayed S, Apold J, Paulsen BS. Comparative studies on tree pollen allergens. III. A purified low molecular weight major allergen from birch pollen (*Betula verrucosa*) isolated by gel permeation chromatography. *Int Arch Allergy Appl Immunol* 68, 70-78, 1982.
 12. Wood RA, Eggleston PA, Lind P, et al. Antigenic analysis of household dust samples. *Am Rev Respir Dis* 137, 358-363, 1988.

Address:

Turid Dybendal

Allergy Research Group

Laboratory of Clinical Biochemistry

University Hospital

Haukeland sykehus

5021 Bergen

Norway