THE MEASUREMENT OF INDOOR ENVIRONMENTAL PARAMETERS IN A NEWLY STARTED AND REFURBISHED SCHOOL

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ABSTRACT

The aim of the study was to follow changes in allergens and airborne particles in the indoor environment during the first year in a newly started school. The building is from the sixties and was refurbished during the summer to be made suitable as a school. New internal walls and some new flooring were installed, and walls and ceilings were redecorated. Most of the furniture, textiles and lamps are new.

Samples for allergen determination were collected by sampling settled dust with a vacuum cleaner. Airborne allergens were collected by a newly developed method involving an ionisator. These samples were anlysed for content of cat and dog allergen. Generally the incoming air was of good quality regarding particles and microorganisms. After about two months the allergen levels had built up to levels between 1-6 µg/g dust, levels regarded as moderate risk for sensitization. Airborne levels also quickly increased and varied depending on activity levels.

KEYWORDS: air quality, allergens, children, schools, TVOC

INTRODUCTION

The relative increase of allergies and other hyperreactivity diseases in the developed and developing parts of the world appear to be due to one or more environmental factors. Today almost every third to fourth child has had ashma, allergic hay fever or atopic excema. Indoor allergens such as house dust mites, furred pets and cockroaches seem to more often cause asthma, while pollen allergens cause hay fever. This difference is probably due to the physical dimensions of the particles, as pollen particles are relatively large and do not penetrate as low into the bronchial tree as the indoor allergens. The sick-building syndrome (SBS) is a type of "other hyperreactivity" which is directly linked to the indoor environment. Changes in the indoor climate such as in homes, day-care centres, schools and offices have been linked to SBS, but have also been suspected as a contributing factor to the increase in atopic diseases. There have been drastic changes in building construction methods and ventilation during recent decades. Children born during the autumn, who therefore spend most of their first few months indoors, are more often sensitized to indoor allergens than children born in the spring. This indicates the importance of early exposure to indoor environmental factors. Furthermore, there is a higher incidence of asthma in northern Sweden as compared to the south, which has been thought to depend on factors in the indoor climate [1].

The quality of air is of utmost importance in relation to allergic airway diseases and SBS. The concentration of allergenic, microbial, irritating, toxic and other compounds which can influence the airways is of interest. Inorganic gases like NO_2 and ozone and volatile organic com-

pounds (VOC) can act like adjuvants and, in combination with allergens, can drastically increase the sensitization effects. People who are already sensitized can suffer from onset of symptoms by many irritating and strong smelling compounds. The presence of infectious agents is also of interest since these can facilitate sensitization.

Indoor air consists of outdoor air, which can be contaminated by particles, fibres, and compounds originating from filters, insulation and settled dust on its way through the transport system in the buildings. If the air is damp the resulting microbiological growth can further pollute the air. Pollution in the room occurs from human activities such as cleaning, cooking and keeping of pets. Besides those are contributions from smoking, fireplaces, materials from building- and interior decoration and various types of household apparatus. Particulate matter can settle on all surfaces and can whirl up depending on the rate of activity in the room. For example, children playing in a school drastically increase the dust concentration in the air. The most important source of bacteria in the indoor air is from people.

The aim of this study was to follow the build-up of indoor allergens such as cat and dog allergen in a newly started school in the Uppsala region in Sweden. Samples for allergen determination were collected by sampling settled dust with a vacuum cleaner, and airborne particles by use of an ioniser. Airsamples collected by airpumps on special adsorbents were analysed by analytical methods in a gas chromatograph and mass spectrometer to estimate the presence of specific volatile organic compounds (VOC). The outdoor and indoor air was analysed by the CAMNEA method for total bacteria and fungi. Furthermore, we studied particles in the air from ventilation intake ducts by collection on a filter electrode followed by analysis by scanning electron microscopy.

METHODS

Background: The school is situated in a village in the Uppsala region in Sweden. The building is from 1965 and was formerly a home for elderly people. The building has a basement under its whole area. In the summer of 1999 the building was totally renovated to be made suitable as a school. These included subdivision of rooms, redecorating and mostly new linoleum on the floors. Most of the interior decorations such as furniture, textiles and lighting were newly purchased. Some curtains and mats were moved from a former school, but the curtains were cleaned before fitting. The school is for children in grade 0-5, that is between 6-10 years of age. The tuition is held in age-mixed groups and the children move a lot from one work-station to another and they also work a lot on mats on the floor.

Samples were collected from two classrooms;

- Classroom 1 was smaller and housed 22 pupils for about 5 hours a day; among those pupils 8/22 (36%) had cats (totally 14 cats) and 6/22 (27%) had dogs (totally 7 dogs) and some had both
- Classroom 2 was larger and housed up to 55 pupils and staff over a day for about 9 hours a day; among those 12/55 (22%) had cats (totally 15 cats) and 10/55 (18%) had dogs (totally 12 dogs) and some had both

Collection of allergen samples: Samples of settled dust were collected by use of a vacuum cleaner fitted with an extra filter bag (Allergen control plc., USA/Medeca AB, Sweden) which was inserted into the vacuum cleaner pipe. An area of 1 m^2 was vacuum cleaned for 4 minutes, after which the filter bag was sealed in a plastic bag and stored at –20°C until extraction.

Airborne allergens were sampled using an ioniser (Airpoint AB, Sweden). Ionisers work by sending out negative ions into the air so that the particles become charged. These negatively charged particles are then attracted to a positively charged collector plate. The advantage of this device is that it is quiet, very easy to handle and collects particles below 0.5 µm in diameter. The ioniser was fitted with a petri-dish as collector plate in order to capture allergenic particles with a conductive surface of 47 mm in diameter (GP plastindustri, Gislaved, Sweden). The ioniser was placed about 1.5 metre above the floor and a new petri-dish was fitted to the ioniser. The sampling period was 24 hours, after which the petri-dish was covered with a lid and stored at –20°C until extracted [2].

Samples of settled dust were weighed and 100 mg dust was extracted (1/20 w/v) by rotating mixing for 2h at room temperature in phosphate buffered saline containing 0.05% Tween. Samples were then centrifuged at 4 500 rpm for 15 min. The supernatants were transferred to new test tubes and stored at –20°C until analysed for the content of allergen.

Extraction of the air samples was performed with 1 ml of phosphate buffered saline containing 0.05% Tween 20 and 0.2% BSA (Bovine serum albumin, Sigma, USA). The petri-dishes were shaken on a plate-mixer fitted on an IKA Minishaker (Tamro Med-Lab, Sweden) for 2h at room temperature. The solution was transferred to a tube and stored frozen at –20°C until analyzed.

Measurement of allergen concentration by ELISA The levels of Fel d 1 and Can f 1 were determined by a two-site sandwich ELISA using monoclonal antibodies [3]. The assays were performed according to the protocols provided by the manufacturer (INDOOR Biotechnologies Ltd, USA, Professor M Chapman). In the dog assay the horseradish peroxidase labelled goat anti-rabbit Ig was purchased from DAKOPATTS, Sweden. The dust samples were diluted in phosphate buffered saline containing 0.05% Tween 20 and 1% BSA in serial dilution beginning with 1/5 and assayed in duplicate. The air samples were assayed undiluted and in duplicates. Allergen levels in the settled dust were expressed as ng/g of dust and those in air samples as pg calculated as the total amount recoverd during the 24 hour collection time.

Collection of air samples for the analysis of volatile organic compunds (VOC) and microorganisms was performed with a portable Universal flow sample pump (Cat. No. 224-PCXR8, SKC Inc., USA) with a flow rate of about 0.4-0.6 l/min for 4 hours.

For the collection of VOC samples the air was passed through a special adsorbent tube, Anasorb 747 containing 210 mg of beaded carbon (SKC Inc, USA) fitted to the inlet tube of the airpump. The total sampling volume was about 100-140 litres of air. After collection the adsorbent material was extracted with 1 ml of dichlofomethane (capillary GC grade suitable for environmental analysis, Aldrich 41,475-1, Sigma, USA) by shaking for 30 min. Analysis was performed with a Hewlett Packard 5890 gas chromatograph equipped with a capillary column DB-5 (60m x 0.32 mm, film thickness of 1 µm, J&W Scientific, USA) connected to a HP 5971 mass spectrometer detector used in the SCAN mode (Hewlett Packard, USA). The total VOC concentration (VOC with a boiling point ranging between 80-300 °C) was expressed in toluene equivalents, using an external standard for toluene (Fluka 89677, Sigma, USA).

Microorganisms in the air were collected by pumping air through a 25 mm Nucleopore filter cassette fitted to another inlet tube on the pump (Multimetrics Inc, USA). These cassettes contained sterile particle-free polycarbonate filters with a pore size of 0.4 µm (BioHospital AB, Sweden). The particles collected on the filters were analysed for total bacteria and fungi according to the CAMNEA method [4].

Investigation of airborne particles in the incoming air was performed by sampling at the outlet duct in the room. Airborne particles were collected on a small conductive plastic filter electrode (Sempore AB, Sweden) fitted to a membrane vacuum pump (Alitea, Sweden) with a flow rate of 1 l/min for 25 min. Particles down to 0.1 µm in diameter can be collected. After sampling the filter electrode was covered with a thin layer of conductive material, namely gold, and analysed by Scanning Electron Microscopy (SEM). The SEM was equipped with an EDS-system (Energy dispesive x-ray spectrometry) making it possible to differentiate between organic and inorganic particles.

RESULTS

Concentration of cat and dog allergen

The concentration of cat and dog allergen present in the two classrooms before the start of the school term in August –99, during the term and finally during the term holiday in January 2000 is presented in Fig 1a-d. The first column in each pair represents samples of settled dust collected from a mat in the classroom and the second value represents the total amount of allergen present in the air sample collected by the ioniser during 24 hours. In classroom 1 there was no mat present in the room until Oct-99, therefore in Aug-99 the value represents a sample taken from the linoleum floor and in Sep-99 it was not determined.

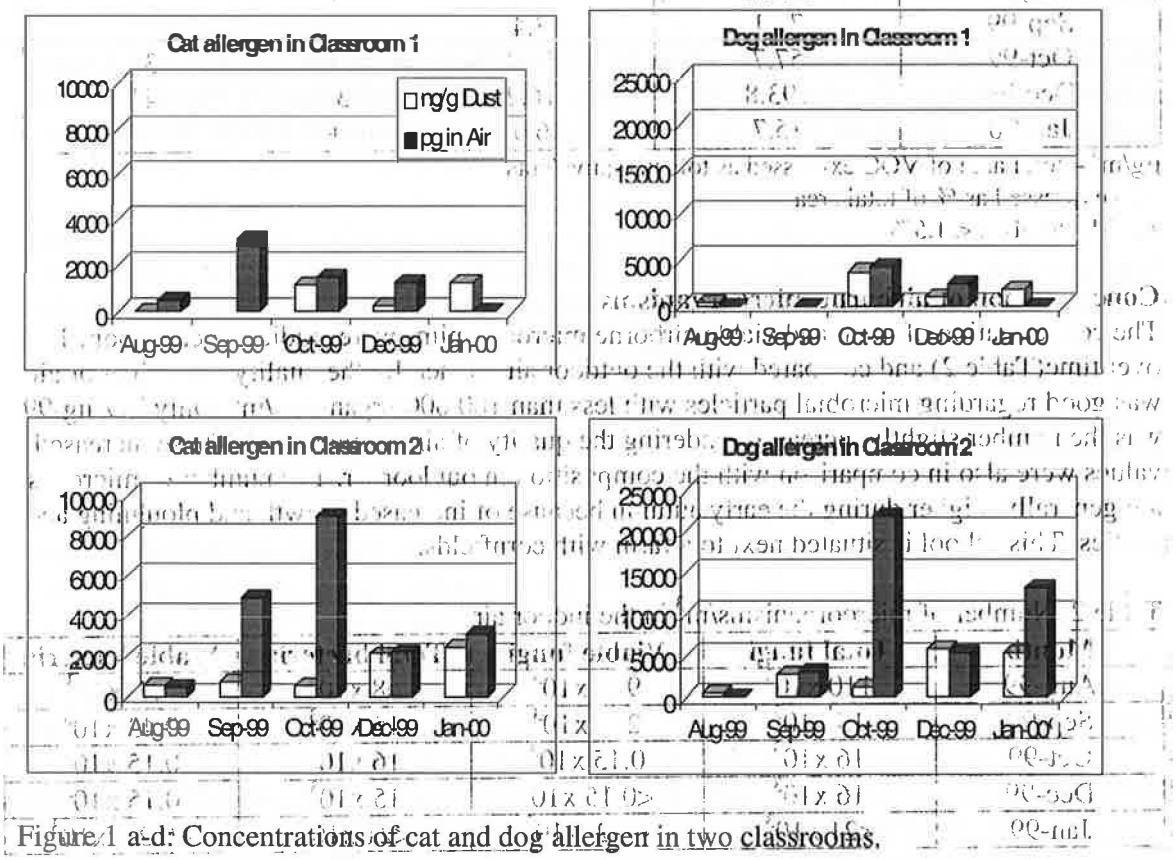

Figure 1 a-d: Concentrations of cat and dog allergen in two classrooms.

Before start of term the levels of cat or dog allergen present in the reservoir was very low and in the airborne samples they were undetectable. During term the allergen concentrations gradually increased both in the settled dust and in the air samples over time. Samples collected during the term holiday (Jan-99) showed undetectable levels of airborne cat and dog allergen in classroom 1, where there were no pupils and consequently no activity, despite the

fact that the allergen levels in the dust were the same as during school term. In contrast in classroom 2, where there was leisure time activity during the holiday, allergen levels in the air were as high as during the school term.

Concentration of total VOC

Samples for total VOC determination were collected in classroom 1 and are presented in Table 1. Generally there was a reduction in the total VOC concentration from start of school in Aug-99 to Jan-00. This is in agreement with what can be expected, namely high levels of chemical emissions in the newly refurbished and redecorated school which declined with time. In Dec-99 there was an increase of total VOC including the presence of two new products, which were not present at the start, namely limonene and 1-metoxi-2-propanol. These products are common in various cleaning products. This could indicate that a general cleaning could have taken place at the end of school term, which correlates with a drastic decrease in allergen levels in the settled dust in the mat in classroom 1 (Fig 1a-b).

Table 1. Concentration of total VOC

Month	total-VOC (indoor) ($\mu g/m^3$)	total VOC (outdoor) ($\mu g/m^3$)	limonene %	1-metoxi-2-propanol %
Aug-99	310.0	5.9	+	+
Sep-99	71.1	7.4		4
Oct-99	57.7	14.4	+	32
Dec-99	193.8	16.2	37	41
Jan-00	15.7	6.5	+	

$\mu g/m^3$ – total area of VOC expressed as toluen equivalents
% - expressed as % of total area
+ - identifiable, < 1.5%

Concentration of airborne microorganisms

The concentration of total and viable airborne microorganims were studied in classroom 1 over time(Table 2) and compared with the outdoor air. Generally the quality of the indoor air was good regarding microbial particles with less than 100 000 organisms/m^3. Only in Aug-99 was the number slightly increased rendering the quality of air as quite good. These increased values were also in comparison with the composition in outdoor air. The number of microbes are generally higher during the early autumn because of increased growth and ploughing activities. This school is situated next to a farm with cornfields.

Table 2. Number of microorganisms/m^3 in the indoor air.

Month	Total fungi	Viable fungi	Total bacteria	Viable bacteria
Aug-99	110×10^3	9×10^3	68×10^3	1.7×10^3
Sep-99	15×10^3	2×10^3	15×10^3	0.43×10^3
Oct-99	16×10^3	0.15×10^3	16×10^3	0.15×10^3
Dec-99	16×10^3	$<0.15 \times 10^3$	15×10^3	0.15×10^3
Jan-99	$<21 \times 10^3$	$<0.2 \times 10^3$	$<21 \times 10^3$	$<0.2 \times 10^3$

SEM analysis of the incoming air

Samples were taken in Aug-99 and in Jan-00 from the incoming air sampled at the outlet duct in the room. At the start of school term the incoming air had several particles of various organic origin present as seen in Fig 2a. During term the size of the class7 filters were changed to a larger size area resulting in almost no particles present at all (Fig 2b) resulting in classifi-

cation of the incoming air as very good. The improvement was most probably due to two factors, the change in filter size and the fact that the ventilation system had been in use for some time after refurbishing and the channels had been cleared from all building dust.

Figure 2a. Incoming air at start of school term

Figure 2b. Incoming air at 5 months after start

DISCUSSION

On the whole the quality of indoor air considering microorganisms and the presence of other particles can be regarded as good. The concentration of VOC has also reduced to normal levels after redecoration of the school before start of term. It is surprising, however, how fast the cat and dog allergen levels built-up after start of this new school. Already in Oct-99 the concentrations of cat and dog allergen had reached above 1 µg/g dust and in Dec-99 levels were over 5 µg/g dust. This rapid increase in allergen levels must depend on the pupils carrying allergens on their clothes from their pets at home to school [5]. According to the guidelines for allergen levels in the environment the presence of 1-8 µg/g dust is regarded as a moderate risk factor for sensitization.

The measurement of allergens in the air showed that the levels vary depending on the rate of activity in the classrooms, increasing during school term down below detection in classroom 1 during holiday when no pupils were present even though the reservoir levels were the same. The majority of cat allergens are carried by particles less than 2.5 um in diameter. The size of the particle plays an important role in allergic effects. First, it affects the rate of settling time and the length of time the particle remains airborne, ie it takes six hours for a particle <2.5 um to settle. Secondly, the particle size determines where the particle is deposited when inhaled by the humans, that is smaller particles like cat and dog allergens may deposit into the alveoli. Thus, those children allergic to cats and dogs may experience a rapid onset of asthmatic and allergic symptoms in these classrooms where the air is disturbed by playing children.

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