Indoor environment in Dutch primary schools and health of the pupils

INDOOR ENVIRONMENT IN DUTCH PRIMARY SCHOOLS AND HEALTH OF THE PUPILS

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ABSTRACT
The indoor environment in Dutch primary schools is known to be substandard. However, it is unknown to what extent the health of the pupils is affected by the indoor school environment. The relation between the indoor environment and pupils' health is examined by performing exposure measurements, building inspection and a questionnaire survey on pupils' health and domestic exposure. Multivariate analysis by principal component analysis showed the importance of both the school and domestic environment to the pupils' health. In case of both highly polluted domestic and school indoor environments, improving conditions at school alone will not result in improved health conditions of the children.

INDEX TERMS
Classrooms, Indoor environmental quality, Building characteristics, Health symptoms, Principal component analysis

INTRODUCTION
Schools are characterised by classrooms occupied by a large number of pupils. These pupils produce pollutants, such as CO_2, moisture, bioeffluents and dust. Moreover, building components, furnishings and equipment contribute to the release of indoor air pollutants such as microbial contaminants, volatile organic compounds (VOCs), formaldehyde and plasticizers (EFA 2001). Adequate ventilation is needed to remove these contaminants from indoor air.

In the Netherlands, children are legally bound to spend 15% of their time at school. Several authorities and researchers have conducted measurements in Dutch schools, showing an alarming situation. CO_2 concentrations appeared to exceed threshold values the vast majority of time, and high amounts of settled floor dust and airborne particles were detected. Poor indoor environments are known to affect human health and performance, possibly having serious consequences to children (EFA 2001, Landrigan 1997). However, it is unknown to what extent pupils' health is affected by the indoor school environment. This study aims at assessing the relationships between indoor environmental quality in Dutch schools and pupils' health.

RESEARCH METHODS
The study focuses on primary school buildings situated in the urban area of Eindhoven, the Netherlands, of which the classrooms are in permanent use by 9/10-year-old children. In Eindhoven, there were 121 of such school buildings in 2003. The study aimed at 12 schools participating, which is approximately 10 % of the total number of schools. A random sample on 16 schools is taken (in three terms, n=12, n=2, n=2). After contacting the schools, 11 of them were willing to participate. For each school one classroom is chosen for performing measurements, so a total number of 11 classrooms is investigated.

Building characteristics of the schools, such as building dimensions, building services, interior, cleaning frequency, and pollution sources present in the classroom, are obtained by a checklist investigation.

Between January and March 2004 exposure measurements are performed. In each classroom thermal comfort (air temperature, globe temperature, relative humidity, air velocity) and indoor air quality (CO_2 concentration, relative humidity, and airborne particles in the size ranges ≥ 0.3 μm and ≥ 1.0 μm) are investigated. The parameters are logged at a 6-minute interval during a period of 2 weeks. The measurement setup has been placed at a central

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location in the classroom. The heights of the sensors have been adjusted to the length of children. Analysis of measured data focussed on the hours children were present in class. The first day of measurements has not been considered, because of the possible bias introduced by the intervention. Furthermore, settled floor dust samples have been obtained and analysed for dust mite allergens (Der p1 and Der f1), cat allergen (Fel d1) and endotoxin.

Health of the pupils is assessed by questionnaires, completed by both the 9/10-year-old pupils occupying 10 of the classrooms investigated (n=228) as well as their parents, after the period of exposure measurements. The children's questionnaire, developed by Van de Sandt et al. (1987), reviewed acute health complaints of pupils. Presence of symptoms is examined by the question 'Did you experience <*symptom*> last week at school/last weekend at home?' and 4-point frequency scale. Prevalence of symptoms has been assumed in case of the answers (3) 'Often' and (4) 'All the time', based on frequency tables. Symptoms are aggregated in 6 variables representing symptoms of a certain type; nasal, ocular, oropharyngal, cutaneous, respiratory and general health symptoms (ECA 1989).

The parents' questionnaire reviewed the children's domestic environment as well as the prevalence of asthma, and atopic eczema. This questionnaire is taken and adapted from the International Study of Asthma and Allergies in Childhood (ISAAC 1998).

Differences among the schools, considering school and domestic exposure, and pupils' health, as well as differences between symptom prevalence at school and at home, are examined by nonparametric statistics (Mann-Whitney U, Kruskall-Wallis H). Multivariate analysis has been performed by principal component analysis (PCA) (Jolliffe 1986), using Data Reduction procedure of the statistical analysis tool SPSS 12.0.1. Within the interpretation of the extracted components, eigenvalues ≥ |0.45| have been considered, which is the distinct break of all eigenvalues.

RESULTS

The schools are built between 1930 and 2002, with a mean age of the classrooms of 32 years. The number of pupils occupying each classroom was ranging from 16 to 27 with a mean of 22. Three of the classrooms had mechanical exhaust system, the others had natural ventilation. Hard floor covering was present in 5 classes, 6 floors were covered with carpet. Visible signs of damp were found in 2 cases of which one showed mould growth. Schools are situated in residential areas in the urban area of Eindhoven. All of the classrooms investigated are nonportables.

Measured exposure is shown in Table 1. The indoor environment in the examined classrooms is generally substandard, regarding (inter)national standards and guidelines (ASHRAE 62, CR 1752, ISO 7730, NEN 1089). Only 1 out of 11 schools seems to meet the quality standards considered.

Table 1. *Measured exposure of the 11 classrooms.*

Exposure Factor	$\bar{X}_{median}$	$\bar{X}_{min}$ - $\bar{X}_{max}$
Air Temperature [°C]	20.9	19.6 – 22.4
Mean Radiant Temperature [°C]	20.7	18.4 – 22.2
Relative Humidity [%]	44.6	38.4 – 59.7
Air Velocity [m/s]	0.08	0.05 – 0.10
CO_2 concentration [ppm]	1524	888 – 2112
Airborne Particles ≥ 0.3 μm [counts/min]	22829	15560 – 44071
Airborne Particles ≥ 1.0 μm [counts/min]	944	650 – 2522
Mite allergen Der p1 [ng/g]	< 30	< 30 – 315.9
Mite allergen Der f1 [ng/g]	< 30	<30 – 89.2
Cat allergen Fel p1 [mU/g]	20.9	9.6 – 83.5
Endotoxin [EU/g]*	9779	2896 – 21084

*Due to diverse endotoxin levels resulting from 2 tests, this variable is excluded from further analysis

The questionnaire on pupils' health, distributed among 228 pupils, resulted in a response rate of 99 %. A response of 96 % was achieved for the parents' questionnaire. The percentage of pupils per school, reporting symptoms, varied between 30.4 to 88.0 %, differing significantly between the schools. The number of pupils reporting oropharyngal, respiratory, and general health symptoms also showed differences among the schools. Atopy was reported by 14 % of the pupils, the percentage of nonatopic was 61 %. Mann-Whitney U tests showed no difference existed between the prevalence of symptoms at school or at home, neither for all pupils, nor for atopics and nonatopics.

Principal Component Analysis resulted in 8 components explaining the total variance. The 5 most important components, describing 70 % of variance, are shown in Table 2. High concentrations of particulate matter and the presence of dust sources in schools are related to the percentage of atopic children reporting symptoms as well as the prevalence of oropharyngal symptoms. Furthermore, domestic mould growth and dampness appear related to symptom prevalence.

DISCUSSION

Pupils' health appears to be associated with both the school environment and domestic exposure. Characteristics of the dwelling and domestic exposure are shown in several components of the PCA. Results of PCA show the complexity of the relation between (i) indoor environment and (ii) building characteristics of primary schools, (iii) domestic exposure and (iv) health of pupils. Pollution of both the classroom and dwellings seems a major factor considering pupils' health. This is reasonable, since both the school and domestic environment are closely integrated in children's daily life.

During school weeks children spend most of their time (77 %) in the domestic environment (Van Lynden-Van Nes 1999). In the domestic environment children are possibly exposed to pollution sources that are not present at school, such as pets, tobacco smoke and other combustion products. Moreover, exposure to mite allergen is the largest in the home environment (Amr 2003, Zock and Brunekreef 1995). Upholstered furnishings, carpets and curtains present in the dwelling constitute reservoirs for allergens and settled dust. The importance of the domestic environment is supported by analysis of symptom prevalence among children; no difference is found between the symptom prevalence in a home and school environment. Apart from the home, school is the most important indoor environment children encounter (15% of time, which is laid down by law). This environment cannot be neglected because of the serious indoor environmental problems.

To achieve an excellent indoor environment in schools, air change rates should be increased without having negative influence on thermal comfort. Awareness of the need of ventilation and user-friendly control of the ventilation equipment are of major importance. In future schools, the use of intelligent systems should be considered. The interior of the school as well as building services should be designed to be easily reachable for cleaning and maintenance, which will prevent the accumulation of dust. But: in case of both highly polluted domestic and school indoor environments, improving conditions at school alone will not result in improved health conditions of the children. Even atopic children in whose dwellings allergen avoidance programmes have been executed, should not expect health benefits since execution of these programmes appeared insufficient (Van Lynden-Van Nes 1999). Nevertheless some few individuals might benefit from improved indoor environmental quality (Zock and Brunekreef 1995). This does not mean one is free to keep the indoor environment in schools as it is. The effect of indoor environment on pupils' learning performance and attendance as well as thermal comfort and subjective air quality is evident, which states the importance of an outstanding indoor school environment (Mendell and Heath 2005, Norbäck 1995, Smedje et al. 1996, Wyon 1969).

CONCLUSIONS AND IMPLICATIONS

Pollution of both the classroom and dwellings seem a major factor considering pupils' health. To achieve a healthy and comfortable environment to children, both the school and home environment should improve.

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Table 2. Results of Principal Component Analysis and interpretation of the data. The 5 components explaining >70% of variance, as well as eigenvalues ≥|0.45| are shown. Varimax with Kaiser Normalisation is used as the rotation method, rotation converged after 19 iterations.

Component 1		**Component 2**		**Component 3**		**Component 4**		**Component 5**	
20.7% (20.7)[a]		17.6% (38.3)		14.6% (52.9)		13.8% (66.7)		11.1% (77.8)	
Atopic children occupying dusty classrooms and living in damp houses report more symptoms		In schools with indoor air pollution children are also exposed to air pollution at home		Newer schools, having carpets, more cat allergen, and fewer dust reservoires, are associated with absence of domestic dampness		High symptoms prevalence among children is associated with various school and domestic factors		Classrooms without local temperature control are warmer, and are associated with a decrease of skin symptoms	
A. Building Characteristics & Indoor Environment School									
ABP ≥0.3 µm, max	0.99	CO_2, max	0.91	Year of construction school	0.96	Air velocity, max	0.61	Air velocity, sd	0.86
ABP ≥0.3 µm, sd [b]	0.98	CO_2, median	0.87	Cat allergen Fel d1 sample 1	0.88	Condensation	0.53	MRT, min	0.86
MRT, max	0.89	Window surface	0.85	Cat allergen Fel d1 sample 2	0.84	Use of dust free chalk	-0.46	Orientation West	0.78
ABP ≥0.3 µm, median	0.84	CO_2, sd	0.85	Door surface	0.77	ABP ≥1.0 µm, min	-0.52	Air temperature, median	0.76
MRT, median	0.72	Operable windows	0.83	Mechanical exhaust toilets	0.70	Insulating window panes	-0.55	Air temperature, min	0.74
Plants in class	0.68	Absolute humidity, median	0.79	Carpeted floors in class	0.66	CO_2, min	-0.56	Air temperature, max	0.64
Absolute humidity, sd	0.64	Absolute humidity, max	0.72	Standard cleaning	0.60	Floor surface	-0.64	MRT, sd[b]	0.63
Open Paper bin	0.57	CO_2, min	0.60	Year of construction class	0.50			Absolute humidity, max	0.62
ABP ≥1.0 µm, max	0.50	Settled floor dust	0.51	Separate copy room	0.50			Indoor sunscreen present	0.61
Open dust bin	0.48	Condensation	0.47	Substandard cleaning	-0.45			Mechanical exhaust toilets	0.55
Television in class	0.45	Number of VDUs	0.45	Indoor sunscreen present	-0.66			Absolute humidity, sd	0.51
Mechanical exhaust corridors	-0.49	Insulating window panes	-0.46	Television in class	-0.71			MRT, median	0.49
Floor surface	-0.53	Sink in class	-0.76	Length open shelves[b]	-0.89			Furniture > 3 years old	-0.47
Use of dust free chalk	-0.57	Absolute humidity, min[b]	-0.81					CO_2, min	-0.47
Air temperature, sd	-0.58							Air velocity, min	-0.53
MRT, sd[b]	-0.59							Orientation North	-0.57
Volume of class	-0.71							ABP ≥1.0 µm, min	-0.62
Ventilated copy room	-0.81							Local temperature control	-0.68
Separate copy room	-0.82								
B. Domestic Environment *(% of dwellings)*									
Construction < 1944	0.70	Unvented kitchen geyser	0.78	Construction 1945 – 1974	0.63	Exposure to tobacco smoke	0.59		
Dampness	0.67			Construction < 1944	-0.51	Construction > 1975	-0.51		
Mould growth[b]	0.48			Dampness	-0.66				
Rugs in livingroom	0.46								
Construction > 1975	-0.52								
C. Health of Pupils *(% symptoms reported)*									
Symptoms atopics	0.79					Symptoms nonatopics	0.97	Cutaneous symptoms	-0.65
Oropharyngal symptoms	0.51					Symptoms pupils	0.95		
						General health symptoms	0.93		
						Respiratory symptoms	0.92		
						Nasal symptoms	0.61		
						Oropharyngal symptoms	0.56		

[a] *% of Variance (cumulative in parenthesis)*
[b] *Transformation applied*

ABP: Airborne Particles
MRT: Mean Radiant Temperature

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