DISCUSSION

A sensor array coupled with a PR technique was successfully used to mimic the decipol judgements of a human sensory panel. Through correlation analysis, redundant sensors were identified and removed from the final array, resulting in improved PR performance.

The results of this study are very encouraging, but because of the small number of evaluations performed on a limited variety of spaces, the patterns extracted from the data are likely not applicable to all occupancy conditions, construction types, system performance levels and climatic conditions. If developed from a broader data base, a similar sensor array and PR technique may be able to reliably predict IAP decipol levels over a broad range of spaces. If additional information can be incorporated into the PR algorithm on irritation potential of odorous and non-odorous compounds, the array can be even more useful as a tool for indoor environmental diagnostics and on-line monitoring.

To make the results more meaningful and more consistent, the following improvements are planned for future work on this concept:

1. increase the number of panel candidates
2. improve the training environment by using a climate chamber
3. improve the training by using a mixture of compounds rather than acetone alone
4. evaluate a much larger sample of spaces in different buildings, and in various climates
5. increase the uncorrelated sensors in the array, and add sensors for other environmental parameters, such as noise and lighting, that might impact a panel's judgement
6. input criteria to the PR technique to address compounds that can have an irritation effect on increasing exposure

A more detailed study is in progress which incorporates most of these improvements.

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INCREASED VENTILATION REDUCES GENERAL SYMPTOMS BUT NOT SENSORY REACTIONS

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ABSTRACT

This paper deals with the relationship between sick building problems and the fresh air volume flowrate. Seven junior High School buildings were investigated and two school-classes at each school, in total 264 pupils, were asked to fill in a comprehensive questionnaire regarding their own health and the indoor environment at the school. At the same time indoor climate and technical measurements were conducted. The investigation reveals the magnitude of hypersensitivity among Norwegian school children. It also demonstrates the magnitude of indoor climate problems. The measurements and the self-reported questionnaires indicate that effective ventilation is only a part of the solution to indoor air problems.

INTRODUCTION

The requirements that produce acceptable indoor climate are considerably difficult to quantify. It is especially difficult to achieve a consensus as to the amount of fresh air that is necessary. Since the energy consumed by ventilation systems rises with increasing proportions of outside air, it is important from an energy-economic viewpoint that this proportion does not exceed what is considered acceptable with regard to human health, well being and productivity. In school buildings it is especially important that the indoor environment is satisfactory on account of learning ability, progress and academic achievements.

This paper deals with the relationship between sick building problems, ventilating systems and the outside (fresh) air volume flow rate. At the same time the magnitude of allergic or hypersensitive pupils is fixed and investigated in order to determine whether they had more sick building problems than the "healthy" portion of the children. The paper is based on 3 investigations conducted in Trondheim, Norway during the years 1989-91.

METHODS

Seven junior high-school buildings in Trondheim (Nordic climate) were investigated during the autumn of 1989, (1), (2). At one of the schools the investigation was repeated in the autumn of 1991, (3). All the schools, with the exception of one, were built in the years 1970 to 82. The last school, G, was built in 1887 but was completely renovated in 1983-86. Some main data concerning the buildings is shown in table 1.

Table 1. Characteristic school building data.

School	Age, (years)	Build. constr.	Classroom	Vent. syst.	Heat syst.	Heat recovery
A	15	Heavy	Standard	Mechanical exhaust	Electr. heat panel	No
B	12	---"---	Landscape	Dual-duct with recirc.	Warm air	Rotating heat ex.
C	7	---"---	----"----	----"----	----"----	Run-around
D	16	---"---	----"----	----"----	----"----	Rotating heat ex.
E	12	---"---	----"----	----"----	----"----	----"----
F	16	Light	----"----	----"----	----"----	Run-around
G	3(102)	Very heavy	Standard	Single-duct no recirc.	Water radiator	Rotating heat ex.

Classroom: Standard = 1 class pr room. Landscape = 3 or more classes pr room

Two school classes at each school, in total 264 pupils, were asked to fill in a comprehensive questionnaire regarding their own health and the indoor environment at the school. The pupils were in the age of 12 to 15 years. The meaning of the different questions were explained to the pupils beforehand because of their low age. At one of the schools all 178 pupils took part in the investigation in order to ensure that there were no statistical inaccurancies for the school in which randomly selected pupils (two classes) were studied.

Indoor climate and technical measurements were conducted at each school at the same time as the pupils filled in the questionnaires. The measurements included room air temperature, relative humidity, respirable suspended particles (RSP), the fresh air volume flowrate and the supply air volume flowrate.

The self-administered questionnaires included approximately 55 questions about sex, age, smoking habits, domestic conditions, school environment and climate, personal health, health complaints and indoor climate complaints. The pupils were especially asked to give a statement on whether their symptoms or problems were related to the indoor environment at the school or not.

RESULTS AND DISCUSSION

The questionnaire survey revealed that about 40-50 % of the pupils claimed to be hypersensitive (including allergy and hyperactivity). This is a relative high number, but it is of the same order of magnitude as other investigations done in the Trondheim region. According to the parents (4), about 39 % of 334 children in 10 kindergarten are hypersensitive. Among the 147 employees, 43 % claimed to be hypersensitive. Corresponding numbers are found also among teachers in junior high-schools in Trondheim. It is therefore reasonable to assume that over 40% of the pupils are hypersensitive. This of coarse includes mild to severe problems.

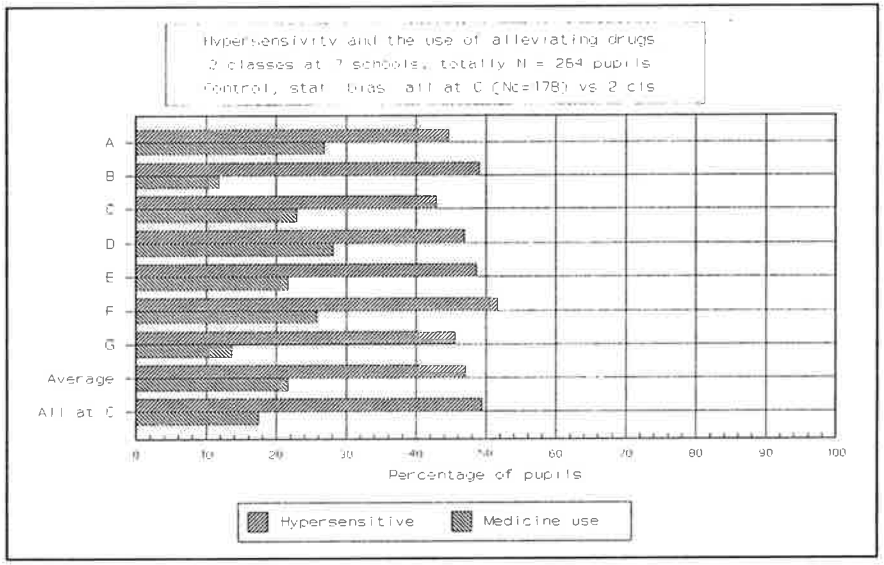

Fig. 1: Hypersensitivity and the use of medicines to alleviate the problem. 7 schools, A-G, two classes at each school, totally N = 264 pupils. Ref. all pupils at school C (N_c = 178).

Figure 1 shows the distribution for the investigated schools. It also shows the distribution when all pupils at one school (school C) are included instead of only two classes. No significant differences are found to be present between all and the selection.

In the questionnaire we asked about medicine used in conjunction with hypersensitive problems. About 20 % of the pupils reported that they use medicines regularly to alleviate their problems. This is quite alarming. Firstly, if so many of the pupils really need medicines, it indicates a severe health problem. Secondly, if only a few of them actually need drugs, then the doctors are not serious enough when they prescribe medicines. Both scenarios are disquieting.

The questionnaire survey indicated that the thermal and indoor air quality problems were of the same kind and of the same order of magnitude as shown in numerous earlier investigations. This also goes for skin complaints, such as dry skin, rash and itchiness, eye problems such as itchy and irritated eyes, sore throat and nose complaints including runny, dry or congested nose. No new information was revealed on that issue.

However, if we look at the mucous membrane irritation symptoms as a group, it is clearly demonstrated that the hypersensitive part of the pupils have significantly more problems than the rest of the pupils. This confirms that general hypersensitivity represents a significant risk factor regarding building related mucous membrane problems.

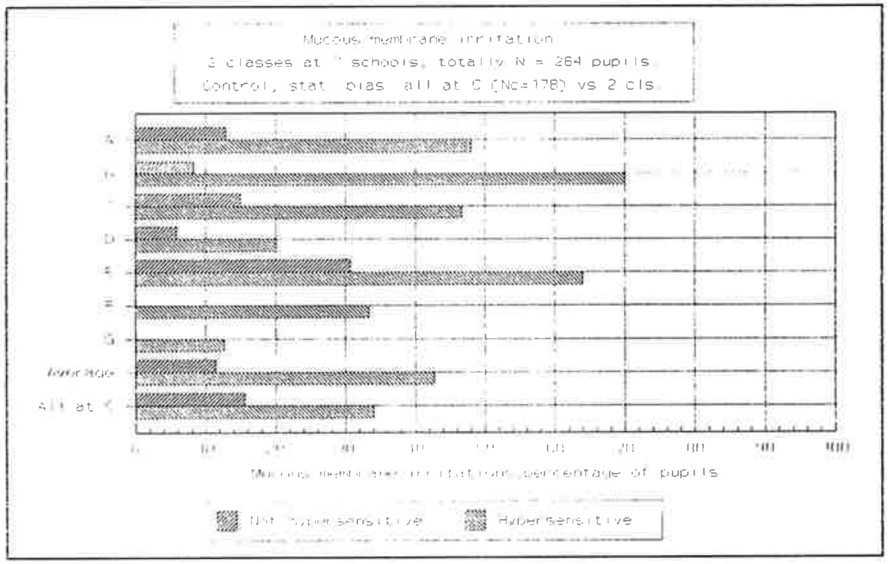

Fig.2: Occurrence of mucous membrane irritations (more than once a week) among hypersensitive and "healthy" pupils.

With regard to nervous system complaints, such as fatigue, lethargy, headache, irritability, etc, no significant differences were found between the two groups of pupils. However, the level of nervous system complaints varied significantly from one school to another.

Many of the pupils felt that their problems were caused by, or made worse by, bad indoor environment at school. The HVAC-plants were therefore examined.

The visual inspection and technical measurements revealed that many of the air conditioning systems did not work as planned. Poor ventilation effectiveness and low fresh air flowrate combined with a high degree of air recirculation was typical rather than unusual. The general findings were therefore inadequate ventilation which resulted in poor indoor air quality (IAQ). This was especially true for warm air heating systems. Regrettably, this is not a new discovery. It is demonstrated a number of times that a combination of ventilation and heating in most cases are a failure, or at least hazardous, with regard to IAQ. The probability for air short-circuiting and poor ventilation effectiveness are too large. Bad HVAC-control amplifies the problems as demonstrated in figure 3. Before lunch there is a clear tendency for short-circuiting, while after lunch the temperature drops significantly. The result is two totally different room air flow pattern during the school-day.

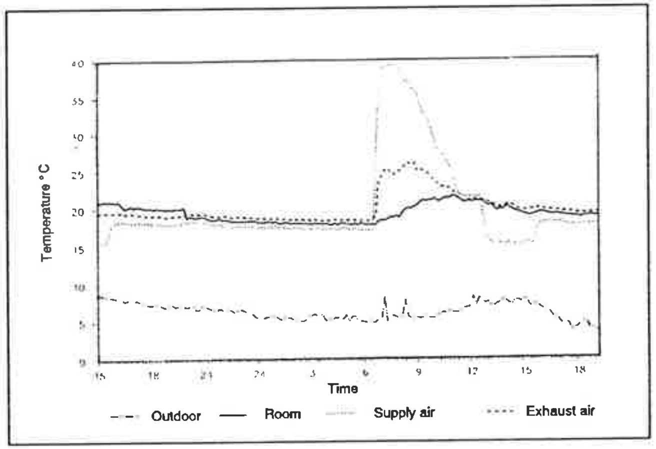

Fig 3. Temperature profiles in a school landscape at school F, Monday 20 and Tuesday 21 of October 1989.

Measurements of suspended respirable particles (RSP) showed about 40 % more dust in rooms with wall-to-wall carpets than in class rooms with linoleum or PVS-flooring. After school hours, with no pupils present, there was no significant difference between rooms with or without carpets. Table 2 shows some of the results. For gravimetrical determination of airborne aerosols, we used a portable piezobalance analyzer with cut size 3.5 μm and a hand held monitor, HAM, for continious measurements of particles less than 10 μm.

Table 2. RSP ($\mu g/m^3$) in class-room with and without wall-to-wall carpets during school hours and after school hours.

School	RSP ($\mu g/m^3$) During school hours		RSP ($\mu g/m^3$) After school hours	
	With carpet	Without carpet	With carpet	Without carpet
A	180 - 230	130 - 200	50	50
B	230	120	50 - 60	70 - 80
C	120 - 140	100	60	60
D	230	-	100	-
E	320	-	20 - 30	-
F	280	160	60 - 100	-
G	380	-	-	-

In spite of the fact that the aerosol concentrations in school hours were well over the Norwegian recommendations (90 $\mu g/m^3$), it was not possible to demonstrate a significant relation between RSP concentration and mucous membrane complaints. Due to the fact that the measured RSP variations were small between buildings, it is not possible to be conclusive on that matter.

Generally, there was little association between the results of the indoor climate measurements and complaints. The only exception was ventilation. The users blamed inadequate ventilation as the main reason for their indoor climate problems and this agrees with our findings. The supply air air volume varied between 1 to 8 l/s · person -

(2 to 14 $m^3/h \cdot m^2$), but due to extensive use of return air, the amount of fresh air was usually very low. Combined with poor ventilation effectiveness and poor HVAC-control, it was reasonable to blame the ventilation system.

In order to investigate this hypothesis, the ventilation system at school C was renovated in 1990. The supply air flowrate was adjusted to approximately 14 $m^3/n \cdot m^2$ (8 $l/s \cdot p$) and no return air allowed. No changes were done with respect to the use or the shape of the classrooms.

In the autumn of 1991 we repeated the questionnaire at school C. At the same time a technical survey was carried out in order to verify that the ventilating plant was still operating satisfactorily with respect to the amount of fresh air.

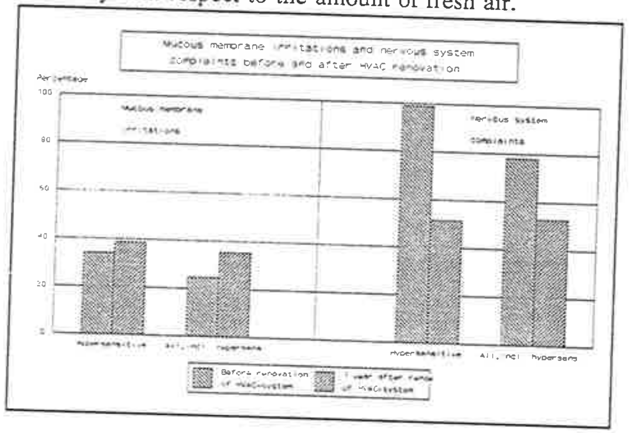

Fig. 4 Mucous membrane irritations and nervous system complaints, school C, before and after ventilation system renovation.

Figure 4 shows that the rate of nervous system complaints had dropped significantly while the mucous membrane irritations are at the same level as before. Although this result concerns only one building, it indicates that increased ventilation reduces general symptoms but not sensory reactions. Removal of fleecy factors, such as wall-to-wall carpets, open bookshelves and wall decorations (dust deposits) are probably equally important in order to reduce this kind of problems.

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MIXED-GAS SENSORS - STRATEGIES IN NON-SPECIFIC CONTROL OF IAQ

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ABSTRACT

While outdoors some known pollutants may be present in higher concentrations a wide spectrum of mainly unknown contaminants is typical for indoor air. The knowledge about combined and long term effects of volatile organic compounds and respirable suspended particles with high adsorptive load on gases and vapors on human health is still fragmentary. But the first step to healthy indoor air is to minimize emissions from sources as building materials, interior (furniture, equipments), HVAC systems, and only secondly by demand controlled ventilating (DCV) systems. DCV systems have to be controlled by sensors. While classical CO_2- and humidity-sensors detect above all human emissions mixed-gas sensors (MGS) are responsible for a large scale of pollutants. Up to now knowledge about mixed-gas sensors is very limited. Experimental studies with metal oxide sensors showed problems in stability, drift and reproducibility. An air mixture (n-Decan, Toluol, 1,1,1-Trichlorethan, α-Pinen, Ethylacetat) was used as standard pollutant. Concentrations were controlled by gaschromatography. High influence of humidity and non-systematic differences in sensitivity between the single compounds are the main dilemma for the practical use of MGS. For constant mixture ratio - the normal case in most of indoor environments - our experiments showed a good correlation with air quality, but simultaneous compensation of air humdity is essential.

INTRODUCTION

In 1858 Max von Pettenkofer (1), a German hygienist, defined the CO_2-value for good indoor air quality. The reason for the use of this metabolic output as an index for all the other emissions of human beings: CO_2 was easy to measure. We are still using Pettenkofer's 0.1%value, but emissions have changed during the last decades. Field studies on perceived air quality (2,3) in several buildings of Copenhagen showed, that less than 1/5 of the pollution load came from occupants and the main emission sources are ventilation systems, building materials and interior. To find a new index for these non-human emissions Pettenkofer would be in a dilemma. Pattern of pollutants varied from room to room, from time to time, depending on temperature, humidity, cleaning procedures, building maintenance, habits, economy, etc.
Both groups of indoor air pollutants may warn man by sensory terms but a stay of some minutes in the room decreases this physiological function by adaptation. Longtime pollution load without sensory feedback mechanisms, as known for thermal and acoustic parameters, are the consequences. For a few pollutants the pathophysiological way to a Building-Related Illness is known, while most of the others may lead to effects, usually called Sick Building Syndrome.