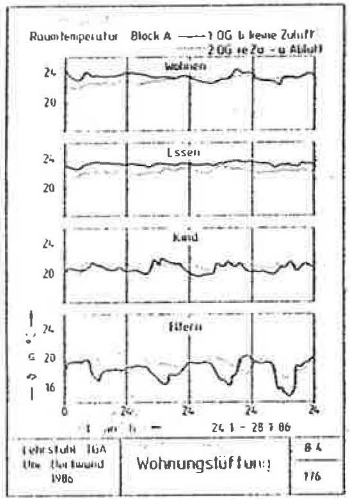


Fig. 5.

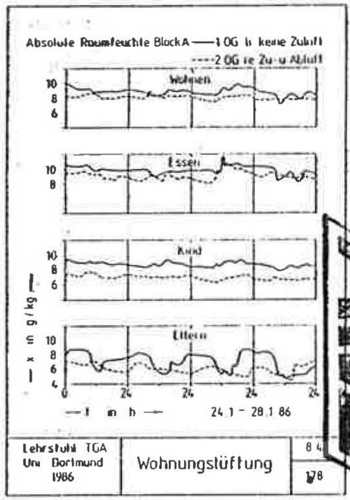
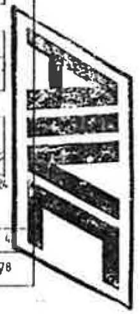


Fig. 6.



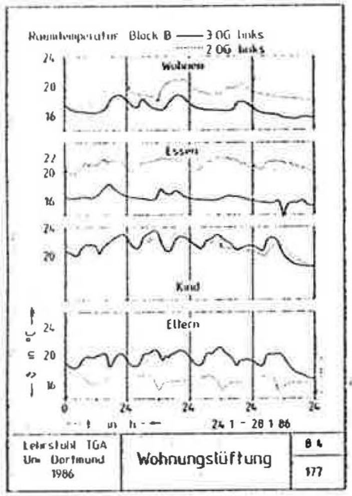


Fig. 7.

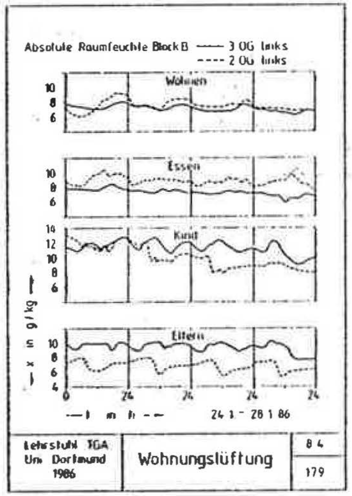


Fig. 8.

SICK BUILDINGS - A VENTILATION PROBLEM ?

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Abstract

A comparative investigation based on climate-technical measurements combined with a questionnaire has been carried out at two schools in Trondheim. At school A there is a normal degree of absenteeism; school B, however, shows an abnormal degree of absenteeism among the staff. As to construction and design the two schools are alike, but there is a big difference in ventilation air flow rates. Low air exchange rate combined with new building materials is probably the main cause of dissatisfaction at school B.

Building and Ventilation Plant

Both schools have load-bearing constructions of reinforced concrete. The outer walls have a facing of light steel-framed insulated sheets. For the partition walls, light mineral wool insulated plaster boards with painted fibre glass net are used. The intermediate ceilings consist of acoustic muffling mineral wool sheets. The rooms used for teaching and the offices have wall-to-wall carpets, boucle in school A and felt in school B.

The ventilation plants are balanced and supply the rooms with filtered air at constant volume and temperature. Projected air flow rates are 15 $m^3/h \cdot m^2$ for school A and 8 $m^3/h \cdot m^2$ for school B. School A has a rotating heat exchanger while school B has a run-around exchanger. The plants are controlled by a timer. The heat transmission loss from the buildings is regained by heating elements at the frontage, water-based convectors for school A and heating foils for school B. None of the buildings have cooling units or humidifiers.

The Questionnaire

Some of the results from the questionnaire are presented below.

No differences are found for the staff at the two schools with regard to age, smoking habits, family life, living conditions etc. Figures 1 and 2 show an extract of the results for the groups teachers/administrative personnel at the two schools.

The investigation show that the teachers have most of the symptoms more often than the rest of the staff. In addition, the difference between the groups of teachers at the two schools are bigger than the other groups of employees.

Fischers accuracy test carried out for several single symptoms shows a significant difference between the groups of teachers. This conclusion is strengthened by the fact that the percentage of those who most often have the symptoms always comes from school B.

Fig. 3 show that the highest percantage of frequent discomfort is found at school B with one exception, temperature.

RESULTS

After consulting the employees the school landscape and connecting group rooms were selected as typical problem area. Most of the indoor climate measurements were therefore concentrated to these locations.

Technical ventilation measurements

The measurements carried out by use of tracer gas show that the air exchange efficiency at shcool B is somewhat worse than a complete mixing. (The air exchange efficiency is defined as the ratio between the theoretically lowest possible mean age and the measured mean age of the air in the room). The air exchange indicators show a certain distortion in the air distribution in the room. (The air exchange indicator is the mean age of all air in the room in proportion to the mean age at the point of measurement).

Table 1. Measured amounts of air flow, school B. Examples.

Room	m^3/h	$m^3/h \cdot m^2$	$l/s \cdot p$	Basis
301, landscape	1830	5,8	3,1	6 classes
302, gr. room	101	4	1	1 class
303, gr. room	156	6,2	1,6	1 class

The concentration level for CO_2 in the group rooms is relatively high. The concentration in room 302 is not measured, but the low rate of air exchange measured means that the level of concentration may raise to 1400-1500 ppm CO_2 in one hour. These values does not, however, represent the maximum level feasible as the measurements are carried out before steady state is reached.

The air exchange efficiency at school A shows that the system works close to complete mixing. Compared to school B, the nominal air exchange is twice as high for school A.

Table 2. Measured amounts of air flow at school A

Room	m^3/h	$m^3/h \cdot m^2$	$l/s \cdot p$	Basis
138 - 144, landscape	5570	12,4	9,5	6 classes
137, gr. room	550	12,4	5,6	1 class

As a whole, the air flow in the landscape at school A is about three times that of school B. As both premises are proportioned for the same number of pupils, this condition will also apply to the air flow per person. Amount of air flow to the group rooms at school B is very low compared to school A.

Generally, the temperature measurements show 21-22^{0}C in the rooms, with a difference of 1-2^{0}C between positions at the ankle and head.

Electrostatic charge and humidity

As none of the buildings have an humidifier, the humidity indoors during winter time will be relatively low. During the period of measurements the humidity were acceptable at about 20-30 % RH. Low humidity combined with wall-to-wall carpets can create electrostatic potentially differences. Human charges at +500 to +4000 volts in proportion to the surroundings were registred. Spark discharges are likely to occur at both schools and this may be a cause of inconvenience.

Dust and fibre

School B has a somewhat larger indoor concentrations of dust than school A. Also outdoor measurements showed higher concentrations for school B. This is especially true for fraction 0.3-3.0 µm. Compared to identical measurements in comparable locations the particle content lie at a normal level.

Table 3. Comparison of dust particles

		Number of particles * 10^{-4} per m^2		Concentration by weight
		0.3 - 3.0 µm	3.0 - 12.0 µm	µg/m^3 (<3.5µm)
School A	Indoor	70 - 470	4 - 115	20 - 30
	Outdoor	80 - 110	2 - 11	<20
School B	Indoor	300 - 620	11 - 130	30 - 90
	Outdoor	260 - 370	1 - 20	

This does not, however, rule out the fact that the dust may be a source of irritations in the respitatory passage and mucous membranes.As mentioned, extensive use of wall-to-wall carpets combined with low humidity leads to electrostatical charge of the staff, which in turn may increse the deposition of particles on the skin and mucous membranes.

The fibre measurements performed showed a very low amount of fibre at both schools. It is therefore not likely to assume that discomfort and irritation may be caused by mineral wool fibres released from the plates used on the intermediate ceiling. At school B, however, mineral wool were placed in some of the air flow shafts. This may, after some time, lead to increased flow of man-made fibres.

Organic gases and fumes, incidence and sources

School B is 6 years old and school A 3 years old. This means that possible non-reacted/non-evaporated dissolutions have had time to evaporate since the schools were built. Gases and fumes in the air were measured by using chromatographic methods.

All of the measurements show concentrations in the range 0.2-0.5 mg/m^3. Numbers of components are very large and go from compounds with a low boiling point (C2 - C3) up to C20. Only a few of the components have been identified. From the ones identified toluene and xylenes are the most dominating.

As the gases and fumes mainly are generated indoors the concentration will decrease with an increase in the air flow rate. At school B a characteristic odour is noticed in areas where wall-to-wall carpeting is being used. This odour is most likely connected to one or more acrylic compounds. Some of them have a very low threshold when it come to odour, about 1 ppb. The assumption that the acrylic are responsible for the odour at school B is based on comparisons of odours. Chemical analyses to prove the sole presence of such compounds have not yet been carried out. Same type of paint is used, both for rooms with and without the above mentioned odour. It is therefore very likely to assume that the source of this odour may be the glue or the foamy plastic backing used for the wall-to-wall carpets.

Lighting and noise

The main source of indoor lighting is warm-white fluorescent lamps. Both schools are satisfactorily illuminated as to measured lux value. The value measured was 5-600 lux compared to recommended value of 300 lux.

The noise level in the landscape at school B is unacceptable, L_{eq}=46 dbA. The main source of noise is the ventilation plant. The noise level at school A is acceptable according to standard. When it comes to infra and ultra sound the level is about the same and the values are acceptable according to today's knowledge. Frequency measurements in the range of 31.5 Hz to 8 kHz showed no abnormal peaks.

Conclusion

The main differences between the two building are the ventilating flow rate, the noise level and the type of floor carpeting. The overall air flow rate at school A is about 9 l/s per person as opposed to 3 l/s per person at school B. It is a reasonable assumption that this is the main cause of discomfort at school B. As we do not know the health hazards caused by contaminants released from many of the new building materials, we propose that the minimum values for ventilating rates should not just be based on body odour and CO_2. We therefore recommend that the air flow rate should be at least 8-10 l/s per person.

References

1. Hanssen,SO, Klyve,LBG, Malvik,B, Mathisen,HM, Sammenlignende inneklimaundersøkelse av to skoler, SINTEF report, Under publ., 1987

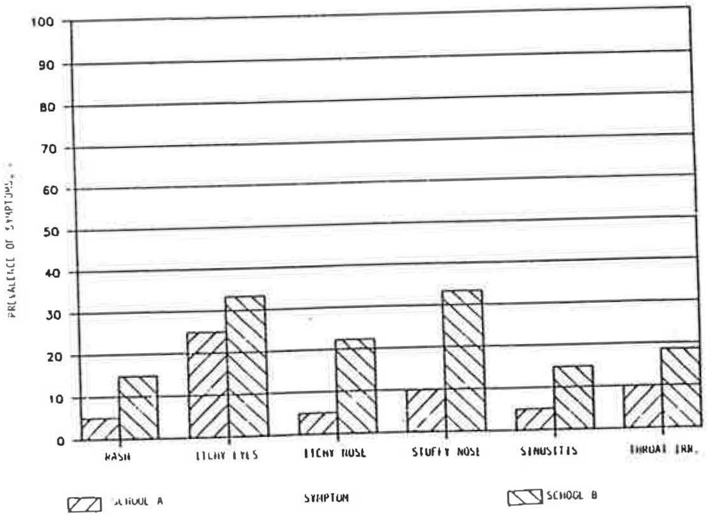

Figure 1.The diagram shows the percentage of teachers/administrative personnel at school A (20 persons) and school B (27 persons) respectively who have frequently (i e more than once a week) suffered from the mentioned symptoms.

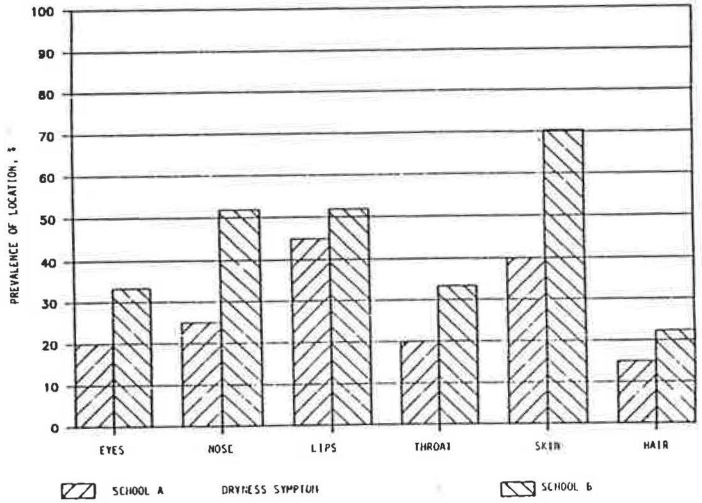

Figure 2. The diagram shows the percentage of complaints related to dryness for teachers/administrative personnel at school A (20 persons) and school B (27 persons).

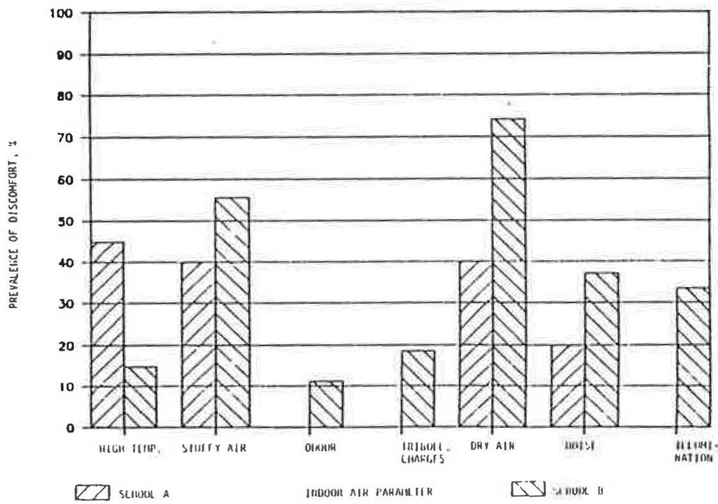

Figure 3.The diagram shows the percentage of teachers/administrative personnel who frequently (i e more than once a week) are feeling discomfort because of the mentioned indoor parameters.