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VENTILATION BEHAVIOUR AND INDOOR AIR PROBLEMS IN DIFFERENT TYPES OF NEWLY BUILT DWELLINGS

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In four types of newly built single family dwellings and in apartments of a block of flats in the Netherlands, the behaviour and motivations of the occupants are studied with respect to their response to heating and ventilation, as well as their judgment on indoor air and climate variables such as tobacco smoke, cooking smells, vapour, mould, dryness, draft and temperature. Knowing the behaviour of the occupants and the building characteristics, estimates are made on the air flows through the dwellings and these air flows are related to stated indoor air and climate problems. The results from the field studies provide recommendations for architects and developers of dwellings and installations and to researchers working on this type of field study. A thesis is proposed that people still define something as a problem, if the resolution offered to solve the problem is also experienced as undesirable.

INTRODUCTION

In the Netherlands during the last few years, the behaviour of occupants of dwellings was studied in relation to the use of energy, as well as their practical experiences with respect to the functioning of several applied radiators, air-heating systems and buildings to save energy. These field studies were carried out by the Netherlands Institute of Preventive Health Care-TNO (NIPG-TNO), in close cooperation with the TNO Division of Technology for Society (MT-TNO, Department of Indoor Environment) and performed in four types of newly built single family terraced dwellings and in apartments of an approximately 20-year-old block of flats. Occupants of 279 dwellings were investigated. The single family dwellings are considered to be a fair representation of the newly built Dutch social housing stock. They are located in the Dutch cities of Almere, Oosterhout, Zwolle and Huizen. The block of flats is ten stories high and situated in the city of Schiedam.

The investigation took place during winter periods with maximum outdoor temperatures varying from approximately +8°C to -5°C during the daytime. In the studies much attention was paid to the behaviour of the occupants with respect to airing and ventilation and the motivations involved. Results of the airing and ventilation behaviour have already been published (van Dongen 1986; Dubrul 1987).

Information was also collected on problems experienced with indoor air and indoor climate variables like tobacco smoke, cooking smells, vapour, mould growth, dryness, draft, and temperature. The central theme of this paper is to give insight into the problems experienced with respect to these variables in relation to the rate of ventilation and to dwelling characteristics. For this purpose, especially those characteristics of the dwellings and of the behaviour of the occupants are reported, which are important for the following three reasons: (1) to estimate the air infiltration into the dwellings, (2) to explain the occupants' perception of indoor air and climate aspects, and (3) to develop recommendations for the occupants, for architects, for developers of dwellings and installations, and for researchers on this field of study.

Since no chemical measurements were carried out, nor health variables explored, no relationship could be assessed between the subjective experiences of the occupants and objective values of health and chemical indoor air parameters. However, from the answers given on open ended questions no indications arose of the appearance of so-called sick building syndrome (Akimenko 1984).

METHODS OF INVESTIGATION

The information about the behaviour and opinion of the inhabitants has been obtained by lengthy face-to-face interviews. Those adults were selected as respondents who are most frequently at home (predominantly women). Other occupants were allowed to assist in answering the questions. In addition, in three of the five projects (Oosterhout, Huizen and Schiedam), the respondents kept a prestructured diary during periods of one or two weeks.

In the interviews, among other things, the frequency of experiencing problems on a number of indoor air and climatic variables was scaled in terms of never, seldom, sometimes, and often, and in terms of negative connotation like too cold. The diaries contain hourly information about presence at home, the use of windows, ventilation provisions, inside doors, and heating systems. Moreover, during 1.5 years in the block of flats in Schiedam, the opening and closing of 1280 windows was continuously registered into a computer by means of the use of sensors (reed relays and magnets) fixed to the window frames.

To assess the validity of the information from the respondents the data from these technical measurements were compared with the results from the diaries. For identical households (n=52) high correlations (Pearson's r) were found: in the winter of 1985/86 a mean correlation of 0.90 was obtained with windows or fanlights opened more than one hour a day, and 0.73 with windows or fanlights opened less than one hour a day, as measured by the sensors. In the winter of 1986/87 the correlations were 0.80 and 0.57, respectively.

The mean amount of time during which one or more windows were opened was 2.7 hours per apartment per day according to the technical measurements and 2.8 hours according to the diaries. Although not as high as the correlations mentioned above, the information from the interviews (carried out just before the diary period of winter 1985 to 1986 and put in more general terms) concerning previously experienced cold and not so cold winter periods, also agree fairly well with the findings from the diaries: 4.7 hours per day a window was opened in not so cold weather conditions and 2.4 hours per day in cold weather conditions.

Given the results of the above mentioned correlation calculations performed in Schiedam, it is reasonable to assume that the behaviour and experience reported in the other locations under study are sufficiently valid as well.

CHARACTERISTICS OF THE DWELLINGS AND THE OCCUPANTS

As stated in the introduction the investigations were carried out in four types of newly built terraced houses and in apartments of a nearly 20 year old block of flats. In Table 1, some characteristics of the dwellings are presented. Except for the project in Huizen all houses are rented and were built under the conditions of social housing programmes. The air tightness of the dwellings is expressed in a measured air change rate per hour (ACH) at a pressure difference of 50 Pascal.

In comparison with a mean ACH value (at 50 Pa) of 12 as measured in standard Dutch dwellings built before 1980, the dwellings of the projects under consideration are fairly airtight and well insulated, especially those in Huizen and Zwolle (de Gids 1985). In Huizen, the bedroom floors are heavier than usual to prevent heat transmission. Some of the dwellings in Huizen also have a façade to a common arcade. In Almere and Zwolle, some of the dwellings are provided with an air heating system, a system which requires a mechanically balanced ventilation and restricted airing behaviour by the occupants.

Four types of windows or ventilation provisions can be distinguished: casement windows (in the Netherlands usually opening outward), pivot windows (with a horizontal axle in the middle), vent lights and ventilation grills (see Fig. 1).

Table 1. Characteristics of the dwellings per location of study.

	Volume (m^3)	n bedrooms	Mechanical ventilation	open plan kitchen	type of windows (consult Fig. 1)	airtightness (mean ACH)	number of dwellings
Almere (rad)	300	4	yes	yes	C,F,G	5	31
Almere (air)	300	4	yes	yes	C,F,G	5	12
Oosterhout (rad)	275	3	no	no	C,P,G	12.9	36
Zwolle (rad)	225	2	yes	80% y	P,G,C	4.1	31
Zwolle (air)	225	2	yes	60% y	P,C	4.1	68
Huizen (arc) (rad)	300	4	yes	yes	P,G	2.9	9
Huizen (rad)	300	3	yes	77% y	P,G,C	4.2	22
Schiedam (flat) (rad)	250	3	no	no	C,F	3.9	70

Codes:
rad - radiator heated; air - warm air heated; arc - front to an arcade; flat - apartment in building; ACH - Air Change rate per Hour of the total dwelling at a pressure difference of 50 Pascal
C - casement window; P - pivot window; F - ventlight; G - ventilation grills

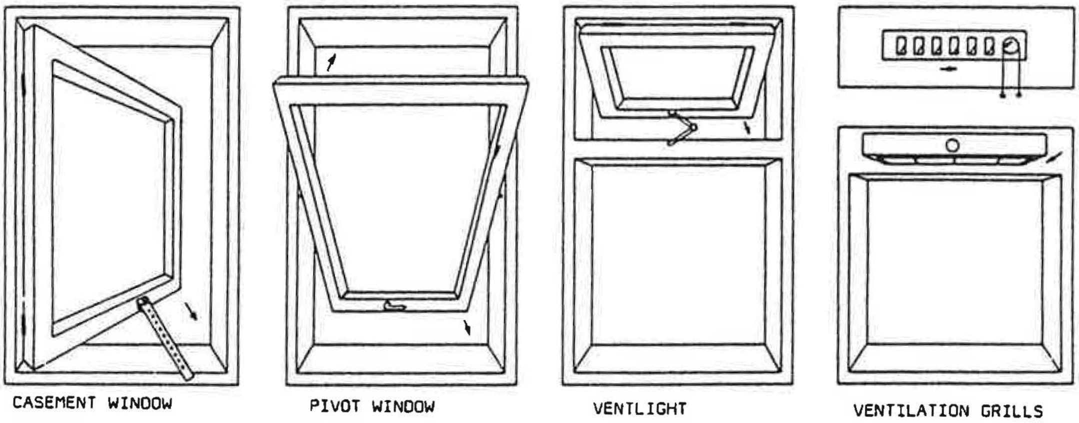

Fig. 1. Types of windows or ventilation provisions applied in the different locations of study; consult Table 1 too.

OBSERVATIONS ON HEATING AND VENTILATION BY BEHAVIOUR

It can be assumed that people tend to adapt the indoor climate and air quality in their dwellings to their own comfort wishes. During the winter the main instruments to attain this are heating and ventilation. It is not surprising that, among a number of other variables, the functioning of the heating system is most strongly correlated with the rate of satisfaction with the indoor climate (see Table 2, based on three locations of study). In the living rooms, the preferred average temperature during the daytime and evening was 20.4°C, about 1°C lower around midday and about 1°C higher in the evening. A large number of

Table 2. Variables correlating with the rate of satisfaction with the perceived indoor climate (Pearson's r; ***: $p \le 0.001$ **: $0.001 \le p \le 0.025$; *: $0.025 \le p \le 0.05$).

	Schiedam	Huizen *	Zwolle	
	flat building (n=70)	heavy bed-room floor (n=31)	radiator heating (n=31)	air heating (n=68)
Satisfaction with the dwelling	0.45***	0.30*	0.47**	0.35**
Problems with:				
-functioning of heating system	0.64***	0.45**	0.56**	0.40***
-cooling	0.02	0.53**	-0.17	0.45***
-cold radiation	0.40***	0.30*	-0.21	0.16
-draft	0.22*	-0.02	0.09	0.23*
-tobacco smoke	0.23*	-	-0.16	0.13
-cooking smells	0.15	0.17	0.02	0.35**

* The two sites in Huizen (see Table 1) are put together here.

the respondents (about 85%) said they preferred fresh and cool bedrooms with temperatures lower than 18°C. This is affirmed by the fact that heating systems in bedrooms are only used one hour per day on the average.

With respect to the ventilation of the dwellings in the studies mentioned above (van Dongen 1986; Dubrul 1987), added to information from other Dutch studies (van Wees 1985; Miedema 1987) a list of factors can be compiled which appear to influence the use of windows and ventilation provisions and which correlate with the rate of ventilation by behaviour.

A number of factors mentioned in Table 3 will be highlighted here. First, the use of windows or vent lights (see Fig. 1) appears to depend on the type of rooms. Figure 2 shows the mean number of hours per day during which windows or vent lights are opened in the different rooms under winter conditions characterized by a temperature of 5°C and a wind speed of 3-5 m/s. It can be concluded that these provisions are used least in the living rooms.

Secondly, the type of ventilation provisions was also seen to influence their use. The smaller the open window surface in the shell of the dwelling, the longer the ventilation provisions are opened. Knowing the open window surface,methods have been developed to calculate air flows (Phaff et al. 1980; Wouters et al. 1987). In Table 4 the main results of these calculations are given (in m^3/ hour), as well as the mean period of time the provisions were opened in the dwelling as a whole (air heated dwellings excluded) and only in the living room (viewed as the room in which the indoor air quality is most critical).

From Table 4, it can be deduced that in living rooms during winter conditions that the mean total amount of outside air through win-

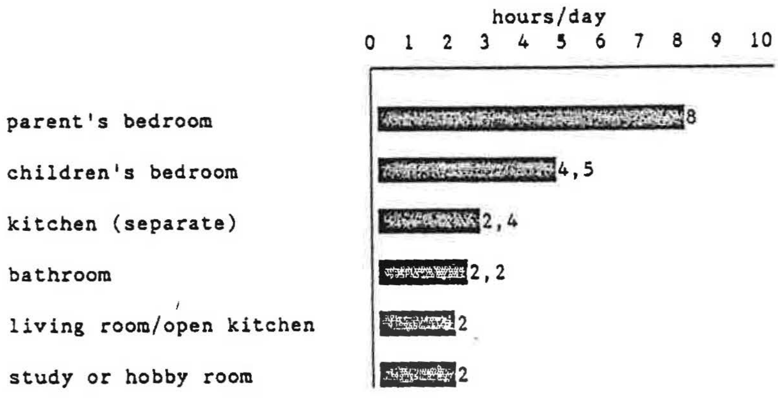

Fig. 2. The mean use of windows and vent lights in different rooms expressed in hours per 24-hour day.

Table 3. List of factors influencing airing and ventilation of dwellings by behaviour.

CLIMATOLOGICAL FACTORS:

* less ventilation when:
  - the outdoor temperature is lower
  - windows are less oriented to the sun
  - windows are more oriented to the prevailing wind direction

HUMAN FACTORS:

* daily patterns in household activities
* less ventilation when:
  - the inside temperature is higher (as preferred)
  - the occupants are less energy conscious
  - the occupants do not smoke
  - the occupants prefer less fresh air
  - no respiratory diseases occur

ENVIRONMENTAL FACTORS:

* less ventilation when:
  - condensation or mold growth are not perceived
  - the moisture production in the dwelling is lower
  - noise or odor annoyance has been experienced from outside

ARCHITECTURAL FACTORS:

* type of rooms
* type of ventilation provisions and heating systems
* less ventilation when:
  - the basic natural ventilation through cracks is higher
  - the volume of rooms is smaller
  - the occupants are conscious of an installed mechanical ventilation (which is not noisy)

dowsand vent lights from outside is about constant and is aproximately 175 m^3 per 24-hours.This level is about 7 m^3 /h. This means that above a given mean natural background ventilation level through leakages in the walls, there seems to be a certain constant amount of air exchange per day which occupants actively try to obtain to feel comfortable. This last fact indicates that people seem to act quite goal-oriented to control the indoor air.

This thesis is supported by a third remark on the factors influencing airing and ventilation: The occupants appear to ventilate more when indoor pollutants are perceived, like tobacco smoke, moisture production, mould growth and cooking smells. For instance where occupants smoke, the ventilation provisions in the living room are used about twice as long as where occupants do not smoke. It also appeared that a higher moisture production (washing

Table 4. The mean use of different types of ventilation provisions in hours per 24-hour day and the calculated mean air flow (in m^3/hour) through these provisions, especially those in living rooms.

	open (window) surface	in whole dwelling (h/day)	in living room period opened (h/day)	mean air flow (m^3/h)	total amount per day(m^3)
casement/ pivot window	0.5 m^2	3	1	200	200
ventlight	0.1 m^2	7	4	40	160
grill	50 cm^2	10	11	7	77 (x 2)*

* Two grilles installed in a living room.

and drying of clothes, showering, and bathing) leads to a more extensive use of bedroom floor windows to get rid of vapour and condensation. The ventilation by behaviour follows a more or less constant daily pattern which can be illustrated in Fig. 3, derived from the field study in the block of flats in Schiedam (figures from Phaff 1986). In this figure, the use of windows, vent lights, and balcony doors in the living rooms, kitchens, and parent's bedrooms are shown. This use is made operational by calculating the percentages of the total number of the particular windows in the block of flats which are opened (y-axis) as a function of the outdoor temperature (z-axis) and the time of the day (x-axis).

With respect to the living room, vent lights appear to be opened independently of the time of day. The balcony doors appear to be opened mostly between 9 and 11 AM which is often related to housekeeping activities. In the kitchens the ventilation provisions are mostly opened during cooking activities in the afternoon and this pattern appears to be relatively independent of the outdoor temperature.

AIR FLOWS AND INDOOR AIR AND CLIMATE PROBLEMS

It has already been stated before that through windows, vent lights and ventilation grilles the average daily air flow into the living rooms is about 7 m^3 per hour in winter conditions of 5°C and a wind speed of 3-5 m/s. Apart from this, the air flow will be much higher because of mechanical ventilation, opened internal door(s) and leakages in the walls. For instance the use of mechanical ventilation provisions installed in the living rooms with an open plan kitchen generates air flows from about 75 m^3 per hour (low speed) to about 170 m^3/h (in dwellings with an air heating system). And through an open internal door (with an open surface of 1.5 m^2) air flows of 300-500 m^3/h are estimated, depending on the temperature difference between living room and hall. The estimations are based on information from Phaff et al. (1980), de Gids (1981) and Wouters et al. (1987).

Table 5 shows for each location the mean space of time during which the different ventilation provisions in the living rooms are opened and the estimated mean air flows per hour during 24 hours. Adding up these mean flows, in each project of the study the total mean air flow through the living rooms can be assumed to be higher and in some cases much higher than 100 m^3 per hour on the average. This conclusion and the fact that the Dutch ventilation standard is based on an air exchange of 25 m^3 per hour per person when a room is occupied, leads to the expectation that the number of indoor air problems in the living room will be restricted.

However, restricting ourselves to the living rooms, it still appeared that in practice a substantial number of occupants often or sometimes experienced problems with condensation, tobacco smoke and cooking smells. Table 6 gives an indication of the extent of these problems. Also problems with indoor climatic factors such as draft, cold radiation, and temperatures are presented, as well as an estimate of the mean total air flows. A conclusion from Table 6 is that, on the basis of the mean values, no relationship can be found between the number of problems with indoor air and climate and the estimated air exchange.

Living rooms can be divided into a hierarchy of three classes: one in which the ventilation is low, one which is characterized as low-plus, and one which is mentioned here as normal. The living room is defined as low-plus ventilated if the follow conditions exist: either casement window open hour per day; casement window ajar 1 hour per day; vent light open 1 hour per day; vent light ajar 4 hours per day; or ventilation grill open 8 hours per day. On the aver-

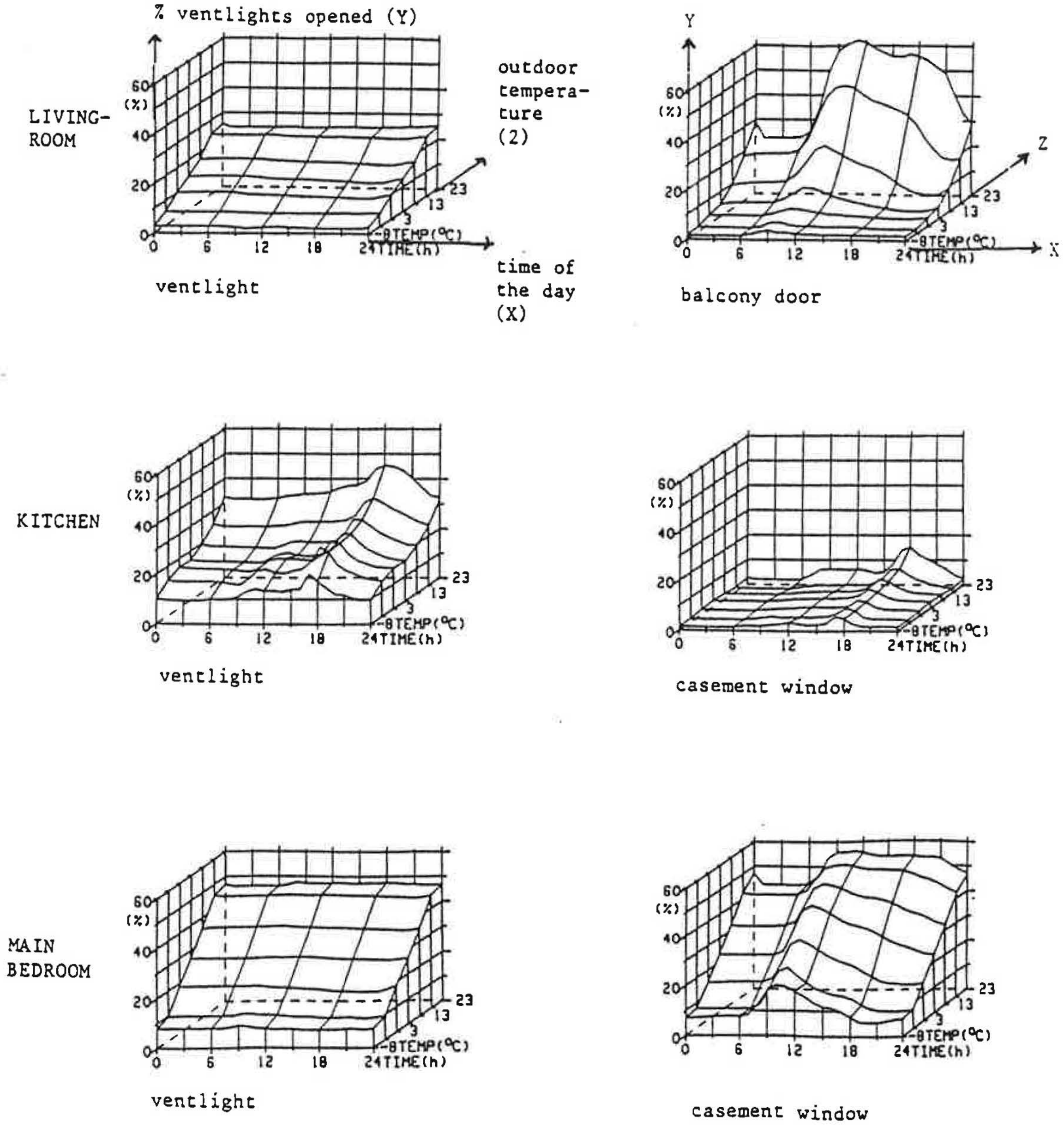

Fig. 3. The use of vent lights, windows, and balcony doors in different rooms (in percentages of the total number in the block of flats (Y) as a function of the outdoor temperature (Z) and the time of the day (X).

age, during 24 hours, this way of ventilating leads to a maximal mean air flow of less than 4 m^3 per hour through these provisions, but in practice the air flow in most cases has at least a tenfold increase as inside doors and mechanical systems are used to ventilate, and in that leakages exist through cracks in the outside walls.

Low ventilation is defined as: limited ventilation (see above); mechanical ventilation 1 hour per day; inward door 1 hour per day opened. In total this generates a maximum estimated mean air flow of about 25 m^3 per hour during a day.

It can be expected that in living rooms where the ventilation is low-plus (which is the case in 25% of

Table 5. Mean hours per day during which different ventilation provisions in the living rooms are used and the estimated main air flows per hour during 24 hours.

proj. nr.	location	in hours per day: outward airing (windows)	outward ventil. (vent lights, grills)	mech. ventil. (low speed)	inward ventil. (door)	estimated mean air flows: in m^3/hour from outside (including mech.vent.)	in m^3/hour from inside by door	through leakages in façades in m^3/h ****
1a.	Almere (rad)	0.7	4.0	1.7	6.4	18	80	11
1b.	Almere (air)	0.8	2.9	24	0.5	182***	10	11
2.	Oosterhout	0.5	7.1*	0	4	7	83	26
3a.	Zwolle (rad)	0.8	24.4*	23	3.2	89	40	9
3b.	Zwolle (air)	0.0	0.5**	24	4.5	171***	56	9
4a.	Huizen (arc)	0.4	55*	20	3.2	70	40	9
4b.	Huizen	0.3	27*	13.9	7.5	48	94	10
5.	Schiedam (flat)	2.4	3.5	0	17.5	26	219	13
assumed air flows in m^3/h (between brackets: project number)		200	2(4a,b) 10(2,3a) 40 (1a,b, 3b,5)	75 (1a,3a, 4a,b) 170*** (1b,3b)	300 (1a,3a,b, 4a,b,5) 500 (1b,2)			

* Sum total of the use of more than one ventilation grill.
** No ventilation grills present.
*** Partly recirculation of air.
**** Based on ACH (Air Change rate per Hour) of the total dwelling (measured at a pressure difference of 50 Pascal) x Volume of dwelling x $\frac{1}{20}$.

Moreover it is assumed that in the terraced dwellings the air flow through leakages in the living room is from 15 to 20% of the flow through air leakages in the total shell of the dwelling. In the block of flats this is assumed to be about 25%.

the dwellings on the average) or low (in airtight living rooms this is the case in about 5% of the dwellings) the proportion of reported indoor air and climate problems differ from living rooms in which the air exchange is characterized as normal. However, this is only found with respect to cooking smells in living rooms without an open plan kitchen (and without mechanical ventilation) and not with respect to condensation, tobacco smoke, too low indoor temperatures, drafts or cold radiation. So while smokers were found to ventilate twice as long, on the average, we can also conclude that stating problems with smoke seem to be independent of the air flow.

EXPLANATIONS ON THE MISSING RELATIONSHIP BETWEEN PROBLEMS AND THE AIR FLOW

With respect to tobacco smoke, a first explanation of this result may be that a doubled period of ventilation time is not sufficient to get rid of it. In this respect, Schlatter and Wanner (1987) can be mentioned as recommending air flow of fresh air between 50 m^3/h per cigarette to avoid strong acute irritations and 120 m^3/h to avoid annoyance due to odour by passive smokers.

A second explanation, however, may be the thesis that people still define something as a problem, if a

Table 6. The rate of indoor air and indoor climate problems and the estimated mean total air flow in living rooms.

IN LIVING ROOM	temperature °C		% often or sometimes problems with						total estimated mean air flow. in m3/h *****	N
	prefered	measured	too cold ****	condensation	too dry	draft/ cold radiation	tobacco-smoke *	cooking smell ***		
Almere (rad)	20.1	20.7	10	32	3	45	37	45	109	31
Almere (air)	20.6	19.7	17	42	0	33	50	67	203	12
Oosterhout	19.5	~19 (17.5/24h)	31	22	6	69	80	14**	116	36
Zwolle (rad)	20.2	19.2	32	6	11	42	11	40	102	31
Zwolle (air)	20.5	20.6	25	2	19	47	16	39	236	68
Huizen (arc)	20.9	21.1	22	0	5	22	0	44	119	9
Huizen	20.3	20.3	27	10	11	18	0	41	152	22
Schiedam (flat)	21.0	20.1	11	31	3	40	24	9**	258	70
weighted mean values	20.4	20.1	21	18	9	44	27	44***	185	279

* In dwelling where > 5 cig. per day are smoked.
** Kitchen separated from living room.
*** If kitchen is in open connection with living room.
**** Too warm was mentioned only twice (in Schiedam).
***** Total of air flows given in Table 5.

solution of that problem (e.g. extensive ventilation) is also experienced as undesirable.

This thesis will be illustrated by two examples: First, problems with condensation on windows appear to be both positively and negatively related to the use of the ventilation provisions. On one hand, condensation problems rise directly from insufficient ventilation times at too low indoor temperatures. But, on the other hand, it is found that, while the condensation problems themselves are solved by longer ventilation, other problems are created like draft, too low temperatures, or fear of using extra energy for heating. In this situation, the occupants may still tend to speak of problems with condensation.

Secondly, mechanical ventilation systems, especially when installed in open plan kitchens, can cause noise annoyance. From a Dutch study on noise annoyance in dwellings, occupants appear to be very sensitive to noise from a mechanical ventilator (van Dongen 1985). At an equivalent sound emission level of 30 dB(A) in an occupied living room, annoyance was sometimes expressed in 25% of the dwellings concerned. So in spite of the positive (although not sufficient) effects of mechanical ventilation on the indoor air quality, the problem of noise from such a device may be associated with, and sometimes verbalized in, terms of problems with smell and vapour.

RECOMMENDATIONS TO PREVENT BAD INDOOR AIR QUALITY

From the field studies reported in this paper it can be concluded that a number of the indoor air and climate problems mentioned above are clearly related to architectural and technological shortcomings. For instance: windows and ventilation provisions which are not easy to regulate; open plan kitchens creating problems with smell and ventilator noise; bathrooms without sufficient ventilation provisions like a window to open; cold air flows and cold radiation from cracks in outside walls; and heating systems which are not capable of warming rooms quickly. These shortcomings may be obstacles to well intended household behaviour or may require strong adaptations of this behaviour. It must be stressed here that occupants are often not average people, but belong to groups with extra health risks.

Moreover it must be prevented that shortcomings in heating systems, as was the case in a number of projects referred to here, lead to an underestimation of the importance of a good indoor air quality. The correlation rates given in Table 2 suggest that problems regarding realization of a satisfactory indoor temperature and prevention of problems with cold radiation seem to determine more the rate of satisfaction with the indoor climate than problems with draft, condensation, and indoor air pollutants such as smoke and cooking smells.

Some remarks can also be made on information campaigns to specific groups of the occupants of the dwellings. Information campaigns directed to promote an optimal occupants' behaviour for obtaining a high indoor air quality will not be successful if the technological and architectural solutions are insufficiently adapted to reasonable behavioural patterns and wishes of these occupants.

One of the objectives of the project in the block of flats in Schiedam was to give written information and instruction about how to ventilate and air the apartments sufficiently in view of the indoor air quality and with a minimal loss of heating energy. The basis of this information campaign was formed by the results of the interviews and the technical measurements of the winter of 1985.

While integrating behavioural aspects like smoking and the experience of aspects of the indoor air and climate, it was found that in about 10% of the apartments, the ventilation tended to be too low, in another 10% clearly too high, and in about 45% very unbalanced: too high in the bedrooms and too low in the living room or kitchen. The information was given in writing and consisted of the following form (Table 7).

Although the effectiveness of this information has not been fully analysed yet, the provisional analyses (controlled for the outdoor temperature) show a slight effect on the behaviour in the winter of 1986 (Phaff 1986; van Dongen 1986). It was found that the fan lights and windows in the living rooms and kitchens were opened 5 to 10% more, especially with outdoor temperatures lower than 10°C. This may indicate that occupants are sensitive to arguments on indoor air quality, in spite of the risk of a higher energy consumption. From a multiple regression analysis performed on the information from the verbal interviews, it appeared that about 10% of the variance in energy use between the apartments in the block of flats in Schiedam is explained by the use of the balcony door or a window in the living room. Wouters et al. (1987) roughly assume an increased energy consumption per year of 12 dm^3 fuel oil or 12 m^3 natural gas on the average for each increased air flow rate from outside of 1 dm^3/s. (On the basis of the mean climatical conditions in Western Europe and a heating system efficiency of 60 to 70%.)

CONCLUSIONS AND RECOMMENDATIONS

A number of conclusions can be derived from the above mentioned field studies in the Netherlands. Reliable, valid, and detailed information on the occupants' daily behaviour and motivations with respect to heating and ventilation can be assessed. This means that predictions based on this behaviour (for instance with given outdoor temperatures) are possible, which in turn enables the calculation of air flows and energy use in occupied dwellings.

Secondly, the assessed daily behavioural patterns indicate that, per household, occupants act quite consistently and goal oriented. One can speak of a subjective rationality in behaviour: people tend to act as well as possible in order to reach a goal, for instance to purify the indoor air.

Subjectively experienced problems with indoor air and indoor climate variables can also be listed. For instance this is useful for obtaining insight into the quality of the dwellings. However, the finding that an expected relationship between the estimated air flows and the problems mentioned is missing, suggests that just posing simple questions on the frequency and the rate of specific problems is insufficient.

The occupants' perception of indoor air and climate problems seems implicitly to include a judgement on the desirability and drawbacks of resolutions available to prevent these problems. In other words: not only the disease is judged but also the remedy.

Table 7. Information in writing on the use of ventilation provisions in the flat building in Schiedam.

Example for the use of windows and doors at normal weather in spring/autumn and winter.

Bedrooms

Day: Large window open 20 minutes (at putting the bedclothes in order) Vent light ajar (1 cm) whole day	**Night:** Vent light half open

Living-room

When the room is occupied: Either: 2 persons - vent light half. 4 persons - vent light full. or: living room inner door open and some windows in bedrooms and kitchen open.	**Night (or room not occupied):** Window closed, except with (more) smokers, then a vent light open.

Kitchen

During cooking: Vent light or casement window open for choice	**After cooking:** Either: vent light fully open for 20 minutes. or: casement window open 5 minutes followed by a half opened vent light for a few hours.

Shower

After use of the shower inner door open 10 cm for some hours.

Remark:
At strong wind and cold periods windows can be open for a shorter time and less wide.
At weak wind and warmer periods windows can be open for a longer time and wider.

This has to be taken into account in future studies on the perception of indoor air quality.

This leads to the last conclusion, especially directed towards architects and developers of dwellings and installation devices. The results of the studies mentioned above suggest that the problems experienced with indoor climate parameters are not predominantly caused by lack of goal-oriented behaviour by the occupants, but by technological and architectural solutions which are insufficiently adapted to the behavioural patterns and wishes of the inhabitants.

A consequence of technological shortcomings may be, for instance, that insufficient heating systems, which mainly determine the rate of satisfaction with the indoor climate, can lead to negligence of the attention necessary to realize a satisfactory indoor air quality.

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