The relationship between health complaints, the quality of indoor air and housing characteristics

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SUMMARY
The energy performance for new houses in the Netherlands increased during the last decade with 45%. A shift from Conventional Mechanical Ventilation (natural inlet and mechanical exhaust or CMV) to balanced flow Heat Recovery Ventilation (HRV) can be seen. Several occupants of the newly constructed neighbourhood of Vathorst in Amersfoort reported health complaints that they relate to HRV. The regional Health Board commissioned a study on health complaints and indoor environmental quality in relation to the ventilation system and other building parameters. 100 dwellings were inspected, divided into a case group of complainers in houses with HRV, a group of similar houses without complainers and a control group in dwellings with CMV. Health complaints occurred more often in dwellings with HRV than with CMV. The quality of the indoor environment was inadequate for the parameters noise, draught, CO2, formaldehyde and high indoor temperatures in summer.

KEYWORDS
Ventilation, Housing characteristics, User behaviour, Health

INTRODUCTION
Problem
The trend towards sustainable building has led to better insulation, air tightness of the building envelope and ventilation systems with high-efficient heat recovery from exhaust air). Heat Recovery Ventilation or HRV blows in and expels air mechanically and recovers heat from the exhaust air. Fresh air is filtered and ducted into the house.

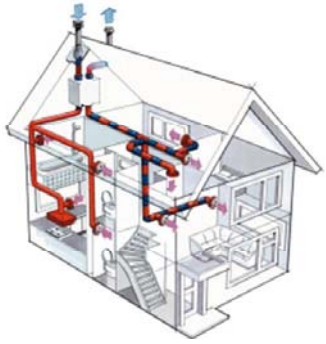

Figure 1. Graph of heat recovery system.
Figure 2. Inlet and exhaust ducts and unit.
Figure 3. Inlet dampers in the living.

In conventional mechanical ventilation the exhaust system is mechanical, with natural inlet through grates and windows.

Figure 4. CMV unit for exhaust from kitchen, toilet and bathroom.
Figure 5. Window for flushing, but without control system for inlet ventilation.

Within a short period of time the regional Health Board in Eemland received reports of poor health from 36 families in Vathorst, a new housing scheme in Amersfoort.

Previous research has indicated that certain health complaints are more prevalent in households with an HRV system (Vietsch, 2006) and that the characteristics of the housing have a strong influence on the quality of the indoor environment and on respiratory problems (Thuis, 1998). The Health Board commissioned an investigation to determine the source of these complaints and the potential connection between health complaints, the indoor environment and the ventilation system in dwellings.

Research questions
1) Do the dwellings meet the legal requirements?
2) What is the quality of the indoor environment in these dwellings?
3) Is there a relationship between the indoor environmental quality and health complaints?

METHOD

Data collection
Out of a total of 278 households in Vathorst that were asked to participate in the research 137 were willing to cooperate. The research consisted of a telephone survey (n=100) in this group and an inspection with measurements (n=100) in the heating season of 2006/2007. The population (n=100) consisted of the case group, the matched group and a control group:

- dwellings with complainers to the Health Board (case group n=25; all except 3 with HRV);
- dwellings with the same characteristics, dwellers did not complain (matched group n=26);
- dwellings with other characteristics, dwellers did not complain (control group n=48).

One person per household responded, the selection was not gender corrected.

The case group with 25 complainers represented the maximum number of households from the 36 complainers that were willing to cooperate. The case group may have influenced the characteristics of the remaining group with HRV, from which the matched group was drawn. All dwellings with HRV (n=51) were compared with CMV (n=48) as well as the matched group (n =26, 23 HRV and 3 CMV) was compared with the control group (n=48, 6 HRV and 42 CMV), in order to have more insight in potential bias. The impact of the negative sentiment in the neighbourhood about HRV on the health perception is not clear.

The survey was based on the Standard Questionnaire on Indoor Environments (RIVM, 2006), the questionnaire of GGD Groningen (Meijer, 2002) and the interview protocol for ventilation behaviour and housing characteristics (Hasselaar, 2006). The themes that were addressed are housing characteristics, resident characteristics, health complaints, occupant behaviour with special attention to ventilation behaviour, satisfaction, cooking appliances. The dwellings were inspected according to the Health Map protocol, compiled at the request of the Ministry of Housing, Spatial Planning and the Environment (Bouwman, 2004). Noise level, thermal comfort, airflow capacity, concentrations of CO_2, formaldehyde and VOS were measured in the living room and (master) bedroom.

RESULTS

Housing characteristics

Two thirds of the homes are owner-occupied and one third rental. Almost all are single-family homes with a separate kitchen. Almost all occupants are first residents. The average occupancy rate is 2.9 persons per dwelling. 50% lived less than 2.75 years and 50% more than 2.75 years in the dwelling. These findings do not explain the difference in complaints.

Resident characteristics

Families with two parents and one or more children accounted for 65% of the research population, two-person households without children for 27%, single-person households for 7% and 1% for one-parent families. The average age of the householder(s) was 37; 6% was older than 55. One third of the dwellings had one child under the age of four and in 3% two children under the age of four. Fifty-five percent of the dwellings had a resident older than 55. In the sample there were no differences in socio-economic status that could influence health.

Health complaints

The common complaints were fatigue (n=19), headaches (n=28), muscular pain (n=7), dry skin and irritated eyes, nose and throat (n=32), frequent colds (n=8), insomnia (n=16), shortness of breath and breathlessness (n=21). No-one rated his/her health as good compared with 12% in the matched group and 19% in the control group. This difference is statistically significant (Cramer's V = 0.266; P < 0.13). Complaints about asthma were only included in the research if they had been medically diagnosed and medication had been increased since moving into the dwelling. Forty-four percent of the residents suspected that their health complaints were caused by the dwelling (Table 1).

Table 1. Percentage of respondents that blamed the dwelling for their health complaints.

Do you think your health complaints have something to do with your dwelling?		Stratum			total
		case	matched	control	
Yes	number	22	13	7	42
	% in stratum	91.7%	52.0%	15.2%	44.2%
No	number	2	12	39	53
	% in stratum	8.3%	48.0%	84.8%	55.8%
Total	number	24	25	46	95
	% in stratum	100%	100%	100%	100%

Strength of association: Cramer's V = 0.634; significance: p < 0.000.

An association was found between the complainers and HRV. The percentage of health complaints was higher in dwellings with HRV than in dwellings with a natural supply of fresh air and mechanical exhaust ventilation. The result is statistically significant, but because of

potential bias in the selected group of complainers, the analysis was conducted without the case group. These results were statistically significant at a 90% reliability level (P=0.1).

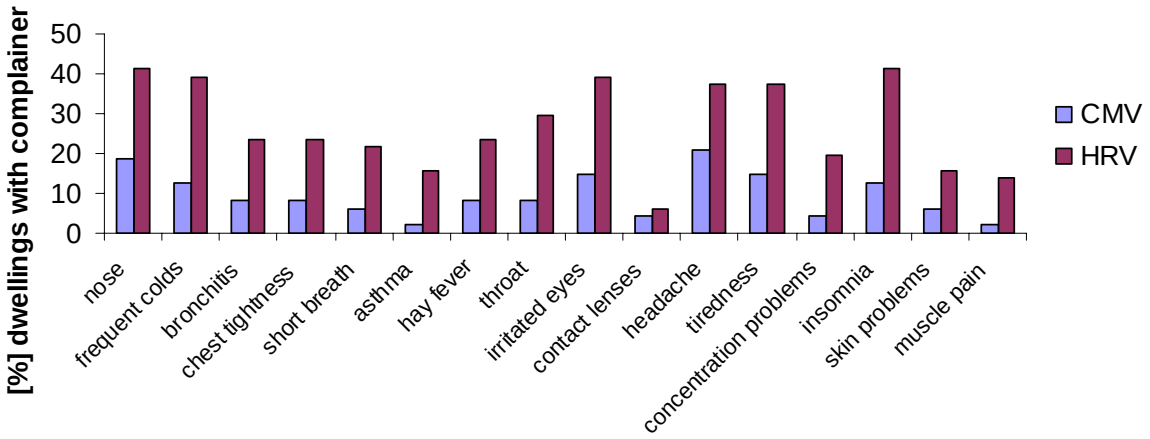

Figure 6. Percentage of non-case dwellings with a health problem.

Figure 6 shows the differences in the health complaints of the matched group and the control group. These relate to complaints which are not experienced outside the dwelling or to asthma which has worsened after moving into the current dwelling. The odds ratio (OR) for the relationship between the variables complaints (independent) and HRV (explanatory) showed significantly higher OR for all plausible complaints (2.9 – 3.9): health complaints occur 3 - 4 times more in dwellings with HRV than in dwellings with CMV.

Occupant behaviour

The survey revealed no significant difference between the groups in terms of renovations and pets. Behaviour relating to smoking, frequency of cooking, washing and showering, the place and method for drying laundry, humidifiers and air fresheners, and the type of floor covering in the living room and bedroom were evenly spread across the groups and the differences between them were not significant.

Satisfaction

The results of the telephone survey indicated that the residents in the control group were significantly more satisfied with their ventilation system than the residents in the case group and the matched group (Table 2).

Table 2. Satisfaction with the ventilation system in each group.

How satisfied are you with your ventilation system?		Stratum case	matched	control	total
(Very) satisfied	number	2	10	36	48
	% in stratum	8.3%	38.4%	75.0%	49.0%
Neither satisfied, nor dissatisfied	number	7	5	4	16
	% in stratum	29.2%	19.2%	8.3%	16.3%
(Very) dissatisfied	number	15	11	8	34
	% in stratum	62.5%	42.3%	16.7%	34.6%
Total	number	24	26	48	98
	% in stratum	100%	100%	100%	100%

Strength of association: Cramer's V = 0.545; significance: P < 0.000.

The main reasons for dissatisfaction were noise and draught from the ventilation system and stale indoor air. Residents with HRV remarked that the indoor temperatures in the summer could rise to unpleasant levels. At the low set point the system does not have enough capacity to cool the indoor climate during the night.

Compliance with building regulations

The visually confirmable housing characteristics appeared to comply with the planning permission. The quality of execution did not vary between dwellings with low or relatively higher energy performance and no connection was found between energy performance and health complaints. The Building Decree prescribes a minimum ventilation capacity of 21, 7 and 14 litres per second for kitchens, toilets and bathrooms respectively. This capacity must be achievable at least in the highest setting. Airflow from a low setting generates 10-30% of the required volume and at set-point 3 at least 100% must be reached. The living room and bedrooms of dwellings with natural air supply met the capacity requirements as opposed to 77% of the dwellings with HRV. The exhaust volume from the kitchen, toilet and bathroom also fell short: 28% of dwellings with CMV and only 15% of dwellings with HRV met the requirements (Table 3).

Table 3. Percentage of dwellings with insufficient climate-conditioning capacity.

	CMV	HRV
Air supply capacity in living room and/or bedroom	Does not apply	33%
Exhaust capacity in kitchen/toilet/bathroom	72%	85%

The positioning (mounted on a wall with insufficient mass), the acoustic insulation and the diameter of the ducts did not fit general guidelines. In addition, in 50% of the living rooms the inlet dampers were in places where draughts and noise are more likely to be noticed, for instance near a dining or sitting area. There are even dwellings with noise levels above 40 dB(A) (Table 4). A significant statistical connection was found between noise and extreme fatigue (Table 5).

Table 4. Percentage of dwellings with noise levels > 40 dB(A).

	Type CMV			Type HRV			total sample		
Setting	1	2	3	1	2	3	1	2	3
Living room> 40	2%	4%	8%	0%	8%	33%	1%	6%	21%
Bedroom > 40	2%	2%	2%	0%	2%	23%	1%	2%	13%

Table 5. Connection between noise of climate-conditioning and extreme fatigue.

	Noise of ventilation (subjective)		
Reporting extreme fatigue	nuisance	not a nuisance	total
None of the residents	37	36	73
One or more residents	20	6	26
Total	57	42	99

Strength of the association: Cramer's V = 0.234; significance: $p < 0.020$

CO_2 concentration

The CO_2 concentration in the indoor air is an indicator of the air quality when people are present (between 7:00 and 23:00 in the living room and between 23:00 and 7:00 in the

bedroom). Table 9 shows the percentage of time that 1200 ppm. is exceeded during the user period of the rooms (Table 6).

Table 6. percentage of time exceeding 700, 1000 and 1200 ppm CO2 concentration.

%	CMV		HRV	
	Living room	Bedroom	Living room	Bedroom
>700	18%	65%	28%	57%
>1000	3%	28%	5%	23%
>1200	1%	17%	2%	14%

DISCUSSION

This survey shows some problems of heat recovery ventilation systems as applied in practice: with low air volume associated with potential indoor air problems and health complaints. A significant connection emerged between noise and extreme fatigue. This could be related to disturbed sleep, fatigue and stress. The residents use the lowest set point in both CMV and HRV systems, thus making it impossible to generate the fresh air volumes recommended by the Health Board and the Building Decree. In dwellings with HRV the inlet air quality may be influenced by the quality of the outdoor air at the inlet point, by dust inside of heat recovery unit, in filters, ducts and dampers, change in perceive quality due to electrically charged dust particles and also dust clouds released after vibrations in ducts and filters etc.

CONCLUSIONS

The research focuses on the statistical relationship between health complaints and the indoor environment, especially the type of ventilation system. The results show that the ventilation capacity failed to meet the requirements of the Building Decree in the majority of the dwellings. Health complaints occurred more often in dwellings with HRV than with CMV. The noise level of Heat Recovery Ventilation is high, which is a barrier for using set points with high air volumes. Health complaints can be associated with shortcomings in the design, construction, use and maintenance of the HRV system.

REFERENCES

Bouwman J.G. et al. 2004. *Gezondheidskaart; opnamemethodiek gezondheidskwaliteit voor gebouwde en nieuw te bouwen woningen* [Health Map: registration method for the quality of health in (proposed) new housing]. Rijswijk: Adviesbureau Nieman.

Hasselaar E. 2006. Health Performance of Housing; indicators and tools. *Ph.D. Thesis.* Delft: IOSpress.

Meijer G. and Duijm F. 2002. *Zuinig warm en schoon; metingen in 28 woningen* [Economically, warm and clean; measurements in 28 dwellings]. Groningen: GGD.

RIVM. 2006. *Standaardvraagstelling Binnenmilieu* [Standard questionnaire for the indoor environment]; Lokale & Nationale Monitor Volksgezondheid. Bilthoven: RIVM.

Thuis H. and Hady M. 1998. *Binnenmilieuonderzoek Utrecht. Een onderzoek naar de relatie tussen woningkenmerken, cara en de kwaliteit van het binnenmilieu* [Indoor environment research Utrecht. Research on the relationship between dwelling characteristics, asthma, COPD and the indoor environment], Utrecht: GGD.

Vietsch C.A. 2006. Motie 28325 nr 34. *Verslag Algemeen Overleg over de energieprestatiecoëfficiënt op 23 februari 2006* [Report on the General Meeting on the energy performance coefficient on 23 February 2006]; 2005-2006, nr 54, Pp. 3544-3549.