CONCLUSIONS

In France, dwelling regulation has enabled the development of efficient ventilation systems. These have to be assessed with regard to heat loss. Performance assessment is an important issue as it may ease the development of new systems with a better efficiency. Nowadays, about ninety percent of new-built dwellings are equipped with mechanical ventilation systems (exhaust systems, balanced systems, DCV systems). The efficiency of different ventilation systems is assessed by methods using computer models which require some assumptions relevant to the occupancy schedule of each room and the virtual pollutant emission rate. Results have shown that the performances of ventilation systems depend on the selected indoor air quality indicator ; research is needed in order to determine the relevant indicators to assess the performance of systems.

ACKNOWLEDGEMENTS

The authors wish to thank Messrs Francis LALBA and Redwan MOUNAJED for their assistance in the development of computer models. The participation of ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie) and MELT (Ministère de l'Equipement, du Logement, et des Transports) is gratefully acknowledged for the research support.

REFERENCES

1. Ribéron J, Millet J-R. Draughts due to air inlets: an experimental approach. Thirteenth AIVC conference on Ventilation for Energy Efficiency and Optimum Indoor Air Quality, Nice, 15-18 September 1992 :369-380.
2. Villenave J-G, Ribéron J, Millet J-R. French ventilation in dwellings. International Conference on "Building design, technology and occupant well-being in temperate climates", Brussels, 17-19 February 1993.
3. Règles Th-G. Règles de calcul du coefficient GV des bâtiments d'habitation et du coefficient G1 des bâtiments autres que d'habitation. AFNOR DTU P50-704. Cahiers du CSTB 2486, livraison 318, Avril 1991.
4. Villenave J-G. Modalités d'instruction des Avis Techniques sur les systèmes de ventilation asservis. CSTB GEC/DAC 92147D, Champs-sur-marne, Décembre 1992.
5. Mounajed R La modélisation des transferts d'air dans les bâtiments. Application à l'étude de la ventilation. Thèse de doctorat, ENPC, Noisy-le-Grand, Octobre 1989.
6. Mounajed R, Ribéron J, Barnaud G. Wind turbulence and ventilation. INDOOR AIR' 90. Fifth international conference on indoor air quality and climate, Toronto, 29 July - 3 August 1990, Vol.4, : 201-206.
7. Bienfait D, Lalba F. Performances énergétiques et qualité de l'aération. Séminaire GEVRA AFME, Sophia-Antipolis, 17&18 Novembre 1987 : 145-157.
8. Thermal performance of buildings - Calculation of energy use for heating - Residential buildings. European Standard (draft) EN 832, CEN/TC 89, Brussels, August 1992.
9. Ribéron J, Gaillard P, Kilberger M. Monitoring humidity-controlled ventilation installations. IEA-ECB Annex 18, Experts workshop on AERECO ventilation systems, Paris, 14&15 March 1991.

VENTILATION RATE AS A DETERMINANT OF SYMPTOMS AND UNPLEASANT ODORS AMONG WORKERS IN DAY-CARE CENTERS

Risto Ruotsalainen, Niina Jaakkola and Jouni J.K. Jaakkola

Laboratory of Heating, Ventilating and Air Conditioning, Helsinki University of Technology and Department of Public Health, University of Helsinki, Finland

ABSTRACT

The objective of this study was to assess the occurrence of symptoms related to the sick building syndrome (SBS) and unpleasant odors among day-care nursing workers, in relation to air flows and ventilation rates in day-care centers. A random sample of 30 day-care centers in the city of Espoo was selected for the study. The study population consisted of 268 female nursing workers, who filled in a questionnaire. Ventilation system in most of the day-care centers (63%) was mechanical supply and exhaust, and the rest of the centers (37%) had mechanical exhaust only. The exhaust air flows in the children's rooms varied remarkably, the range being 0-11 L/s per person (average 4.0 L/s per person). The ventilation rate varied from 0 to 5 m^3/hm^3 (average 1.6 1/h). No consistent associations were observed between the magnitude of air flows or ventilation rate and the occurrence of symptoms or unpleasant odors experienced by the workers. The results indicate that relatively low mechanical ventilation rates are not associated with SBS symptoms and unpleasant odors, in conditions where the potential sources of odor are strong and air exchange is not totally dependent on mechanical ventilation (windows are openable).

INTRODUCTION

It has long been known that infectious diseases are more common among children in day-care centers than among children in other forms of care (1, 2). Inadequately low ventilation rates and high concentrations of CO_2 and chemical and biological pollutants have been measured in day-care centers in the Nordic countries and North America (3-9). However, the effects of different indoor environmental factors and especially ventilation rates have not been sufficiently studied.

A similar set of symptoms experienced by office workers has been called the sick building syndrome (SBS). The objective of this study was to assess the occurrence of SBS symptoms and unpleasant odors among day-care nursing workers in relation to air flows and ventilation rates. This association has not been reported earlier in a day-care center environment, where approximately one third of the Finnish preschool children are enrolled. The hypothesis of the study was that SBS symptoms as well as perceived unpleasant odors are more commonly related to low ventilation rates.

METHODS

Study population

From 112 day-care centers in the city of Espoo, a random sample of 30 day-care centers (27%) and their employees was selected for the study. Espoo is an urban-suburban municipality with a population of 170,000, in the Helsinki metropolitan area. A self-administered questionnaire was distributed to each worker at the 30 day-care centers in March 1991. The questionnaire was returned by 339 workers (96.0% of all). The study population, described in Table 1, was limited to 268 female nursing workers (69 administrative or service workers and 2 male nursing workers were excluded).

Data collection

The performance of the ventilation, the indoor air quality and characteristics of the indoor environment were assessed in the 30 day-care centers studied during October and November 1990 (10). The air flows were measured with momently measurements from the exhaust outlets with a hot wire anemometer and an anemometer tube. The measurements were made when the rooms were occupied and the ventilation systems were operated as usual. The determinants of interest were air flow per person (L/s,person) and ventilation rate (m^3/hm^3) calculated of the exhaust air flows in all the children's rooms.

A self-administered questionnaire was developed in which workers were asked about their personal characteristics, the occurrence of allergic diseases, different infectious diseases, symptoms of the sick building syndrome (SBS) and perceived indoor air quality during the past 12 months, and details of their work and home environments. The outcomes consisted of unpleasant odors (including metabolical, stuffy air, sewage smells, mold, tobacco smoke, chemical and other odors) and such work-related symptoms as eye symptoms (dryness, irritation or itching), nasal dryness, nasal congestion (blocked nose), nasal discharge (runny nose), pharyngeal symptoms (cough, dryness, irritation, itching or sore throat), skin symptoms (dryness, irritation or itching), headache, lethargy and difficulties in concentration during the past year.

Statistical methods

In the crude analysis, prevalence ratios and odds ratios were estimated for the determinant-outcome relations. The determinant-outcome relations were then estimated in logistic regression models, including indicator variates for the ventilation and the potential confounders as covariates. In the final models, the air flows were categorized into three groups: 1) below 2.5 L/s per person (low ventilation), 2) 2.5-<5.0 L/s per person (medium ventilation), and 3) from 5.0 L/s per person (adequate ventilation as reference). The Finnish guide value for day-care centers is 5 L/s per person (11). To provide the best estimate of the relation between the ventilation and the symptoms, the following potential confounders were included in the models: age (15-34 / 35-44 / 45-64 years), atopy (any history of doctor-diagnosed asthma, atopic eczema, allergic rhinitis or allergic conjunctivitis), job (manager or teacher / nurse / assistant or trainee), psychosocial index of work (including psychosocial climate, work stress and interest in work), building type (detached day-care building / in block of flats), type of ventilation system (mechanical exhaust / mechanical supply and exhaust), dampness (including water damage in the day-care center and mold odor perceived by the nursing workers), and any moisture problem at home (including water damage, wet spots, visible mold and mold odor). All the workers in the study population were female.

RESULTS

Ventilation system in most of the day-care centers (63%) was mechanical supply and exhaust, and the rest of the centers (37%) had mechanical exhaust only. The exhaust air flows in the chil lren's rooms varied remarkably, the range being 0-11 L/s per person (average 4.0 L/s per person). The ventilation rate varied from 0 to 5 m^3/hm^3 (average 1.6 1/h). The studied persons, whose personal and environmental characteristics are described in Table 1, were categorized into three groups according to the magnitude of the air flows. The workers in the low ventilation group were older on average and they were more seldom working as nurses. The day-care centers were more often located in apartment buildings with mechanical exhaust only and with signs of water damage.

Table 1. Characteristics of the 268 female nursing workers in the 30 day-care centers studied.

Characteristic L/s,person:	0.0-<2.5		2.5-<5.0		5.0-11.1		Total	
	N	%	N	%	N	%	N	%
Total	87		99		82		268	
Age								
15-34	41	47.1	56	56.6	48	58.5	145	54.1
35-44	21	24.1	16	16.2	24	29.3	61	22.8
45-64	25	28.7	27	27.3	10	12.2	62	23.1
Any allergic disease								
No	59	67.8	63	63.6	57	69.5	179	66.8
Yes	28	32.2	36	36.4	25	30.5	89	33.2
Job								
Manager or teacher	37	42.5	29	29.3	29	35.4	95	35.4
Nurse	21	24.1	45	45.5	31	37.8	97	36.2
Assistant or trainee	29	33.3	25	25.3	22	26.8	76	28.4
Psychosocial index								
Satisfied	51	58.6	66	66.7	49	59.8	166	61.9
Unsatisfied	36	41.4	33	33.3	33	40.2	102	38.1
Building type								
Detached day-care building	52	59.8	73	73.7	63	76.8	188	70.1
In apartment buildings	35	40.2	26	26.3	19	23.2	80	29.9
Ventilation system								
Mechanical exhaust	64	73.6	24	24.2	10	12.2	98	36.6
Balanced ventilation	23	26.4	75	75.8	72	87.8	170	63.4
Dampness								
No water damage or mold odor	11	12.6	37	37.4	27	32.9	75	28.0
Water damage, no mold odor	57	65.5	40	40.4	36	43.9	133	49.6
Water damage and mold odor	19	21.8	22	22.2	19	23.2	60	22.4
Any moisture problem at home								
No	68	78.2	77	77.8	69	84.1	214	79.9
Yes	19	21.8	22	22.2	13	15.9	54	20.1

No consistent associations were observed between the magnitude of air flows or ventilation rates and the occurrence of SBS symptoms or unpleasant odors (Table 2). Of the respiratory symptoms, pharyngeal symptoms were more common among the occupants working in the day-care centers with low or medium ventilation (below 5 L/s per person) than among the workers in the centers with ventilation within the regulations (above 5 L/s per person). Statistically significantly higher was the risk of lethargy (OR 2.15, 95% CI 1.07-4.29) when the air flows did not achieve the guide value of 5 L/s per person; however, the risks of other general symptoms were smaller. Unpleasant odors perceived by the nursing workers were most common with medium ventilation (the occurrence of metabolical odors being statistically significantly higher). According to the crude analysis, the nursing workers in the older day-care centers (constructed before 1981) with mechanical exhaust, experienced significantly more commonly unpleasant odors than the workers in the newer buildings (constructed from 1981 onward) with balanced ventilation (70% / 56%, $p<0.05$).

Table 2. Adjusted odds ratios for work-related SBS symptoms and unpleasant odors in the categories of low ventilation (0.0-<2.5 L/s per person, N=87) and medium ventilation (2.5-<5.0 L/s per person, N=99), versus adequate ventilation as reference category (5.0-11.1 L/s per person, N=82).

Symptom or perception	2.5-<5.0 L/s,person OR	95% CI	0.0-<2.5 L/s,person OR	95% CI
Eye symptoms	0.80	0.32-2.00	0.46	0.13-1.66
Nasal dryness	1.14	0.49-2.68	0.57	0.17-1.86
Nasal congestion (blocked nose)	0.91	0.36-2.31	1.01	0.31-3.30
Nasal discharge (runny nose)	1.07	0.40-2.87	1.28	0.35-4.61
Pharyngeal symptoms	1.39	0.56-3.48	1.81	0.55-5.97
Skin symptoms	0.70	0.32-1.56	0.60	0.22-1.62
Headache	1.16	0.61-2.20	0.79	0.36-1.73
Lethargy	2.15	1.07-4.29	2.16	0.92-5.06
Difficulties in concentration	0.36	0.11-1.14	0.46	0.13-1.66
Unpleasant odors	1.01	0.53-1.92	0.40	0.18-0.90
Metabolical odors	2.99	1.45-6.18	0.75	0.30-1.92

DISCUSSION

Against the hypothesis of the study, no consistent and significant associations were observed between the magnitude of air flows or ventilation rates and the occurrence of the SBS symptoms among the nursing workers in the day-care centers. As an exception lethargy was more frequent in both low and medium ventilation categories than in the reference category (above 5.0 L/s per person). No consistent associations existed with the occurrence of unpleasant odors experienced by the workers, although the CO_2 concentration measured was highest on average with low air flows (below 2.5 L/s per person) (10). The greater risk of lethargy could be explained by the increased CO_2 concentrations, although the lack of dose-response pattern does not favor this explanation.

Exhaust air flows have commonly been used as a measure of the magnitude of air exchange, mainly because they are easy to measure. In a Finnish cross-sectional study of office workers, air flows below 10 L/s per person were associated with excessive SBS symptoms (12). In our study, no such correlation was found, although the air flows were lower. Because of the nature of the work, the day-care workers spend less time in any one room than the office workers; thus the exposure is lower to indoor air pollutants of the room.

In the children's rooms, the exhaust air flows are designed to be lower than the supply air flows, and the internal air flows go, in principle, toward the bathrooms. Measuring the exhaust air flows does not account all the air flows between the rooms and, because of this, the actual outdoor air flows can be higher than the measured air flows. The position of the interior doors has a great influence on this, too.

The air flows were measured only once (during the heating period), whereas the occurrences of symptoms and perceptions were asked over a period of twelve months. The variation of mechanical air flows is usually insignificant over the time, and mechanical ventilation systems are not as sensitive with outdoor climate as natural ventilation systems. Instead, the ventilation through the windows varies with the outdoor thermal conditions; and with low air flows, the window ventilation was slightly more frequent with a corresponding increase in the actual air exchange. An explanation to the results could be the influence of negative feedback: if the occupants are perceiving excessive unpleasant odors, they open the windows more frequently.

Too low ventilation rates may be insufficient in eliminating the indoor air pollutants which have adverse effects on human health and comfort. The exhaust air flows may not be the best measure for the exposure to indoor air pollutants (mainly from human bioeffluents); a better method could be an integrating constant tracer flow technique with which the actual long-term air exchange rate could be assessed.

The results indicate that relatively low mechanical ventilation rates are not associated with SBS symptoms and perceived unpleasant odors among workers in day-care centers, in conditions where the potential sources of odor are strong and air exchange is not totally dependent on mechanical ventilation (windows are openable).

ACKNOWLEDGEMENTS

This study was supported by the Ministry of the Environment, the National Agency for Welfare and Health, the Medical Research Council of the Academy of Finland, and Imatran Voima Foundation. The assistance of all the employees of the city of Espoo who contributed to the study is gratefully acknowledged.

REFERENCES

1. Hesselvik L. Respiratory infections among children in day nurseries. Acta Paediatr, Suppl. 1949; 74:1-103.
2. Ståhlberg M-R. The influence of form of day care on occurrence of acute respiratory tract infections among young children. Acta Paediatr Scand, Suppl. 1980; 282:1-87.
3. Lundqvist GR, Iversen M, Korsgaard J. Indoor climate in low-ventilated day-care institutions. Environ Int 1982; 8:139-142.
4. Olsen JH, Døssing M. Formaldehyde induced symptoms in day care centers. Am Ind Hyg Assoc J 1982; 43:366-370.
5. Steensberg J. Indoor climate problems in day institutions for children. Practical, administrative and policy perspectives. Institution of medical officers of health, Hillerød, Denmark; 1984; pp. 1-39.
6. Nevalainen A, Jantunen M, Pellikka M, Pitkänen E, Kalliokoski P. Airborne bacteria, fungal spores and ventilation in Finnish day-care centers. In: Proceedings of Indoor Air '87, Berlin (West); 1987; Vol. 1:678-680.
7. Sverdrup C, Andersson K, Andersson S. A comparative study of indoor climate and human health in 74 day care centers in Malmö, Sweden. In: Proceedings of Indoor Air '90, Toronto; 1990; Vol. 1:651-655.
8. Pejtersen J, Clausen G, Sørensen J, Quistgaard D, Iwashita G, Zhang Y, Fanger PO. Air pollution sources in kindergartens. In: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; Proceedings of IAQ'91, Healthy Buildings, Washington DC; 1991; 221-224.
9. Daneault S, Beausoleil M, Messing, K. Air quality during the winter in Quebec day-care centers. Am J Publ Health 1992; 82:432-434.
10. Ruotsalainen R, Jaakkola N, Jaakkola JJK. Ventilation and indoor air quality in Finnish daycare centers. Environ Int 1993; 19:109-119.
11. The Ministry of the Environment. National building code of Finland, D2: Indoor climate and ventilation in buildings, regulations and guidelines 1987. Helsinki; 1987.
12. Jaakkola JJK, Reinikainen LM, Heinonen OP, Majanen A, Seppänen O. Indoor air quality requirements for healthy office buildings: recommendations based on an epidemiologic study. Environ Int 1991; 17:371-378.

THE PENETRATION FACTOR AND REMOVAL RATE BY THE BUILDING ENVELOPE FOR SO2 AND NO2 GAS

Julie Seelen[1], Brian P. Leaderer[2], Joop Vorenkamp[3], Kees te Velde[3] and Martin H. de Wit[3]

[1]Indoor Environment Program, College of Architecture and Urban Studies of Virginia Polytechnical Institute and State University, USA
[2]John B. Pierce Laboratory, Dept. of Epidemiology and Public Health, Yale University School of Medicine, USA
[3]Dept. of Architecture and Building Engineering, Eindhoven University of Technology, The Netherlands

ABSTRACT

The study presented here gives an indication of the removal rate of comtaminants by the building envelope. To determine this removal rate and the corresponding penetration factor, a model of a residential building was built inside a controlled exposure chamber. SO_2 and NO_2 gases were injected into the supply air of the chamber, and concentrations in both chamber and model were monitored. The experiments indicated that the building envelope removed part of both gases, resulting in lower indoor concentrations. Exposure of the model to NO_2 gas resulted in elevated levels of NO inside.

INTRODUCTION

Ventilation and infiltration air can bring outdoor contaminants into the indoor environment. Using mechanical ventilation systems, the outside air can be cleaned as part of the conditioning before introduction into the occupied space. For building constructions with natural ventilation, contaminated outside air enters through windows, doors, cracks, and other openings in the structure. The fraction of the contaminants that will be absorbed by the materials that make up the building envelope is the removal rate. The fraction of outdoor pollutant concentration that is not removed by the building envelope, but enters the building, is the penetration factor. The entry and subsequent fate of outdoor contaminants in the building envelope are not well known. The study presented here gives an indication of the removal rate of SO_2 and NO_2 gas by the building envelope. These gases were used because they are major outdoor pollutants and relatively easy to generate and analyze.

METHOD

A mass-balance model has been developed (1), which relates outdoor pollutant concentration, building penetration factor, air exchange rate, indoor sources, and sink rate, with indoor pollutant concentration. This model assumes uniform mixing, and that air exchange rate, penetration factor, emission, and sink rate are constant. The building penetration factor, P, represents the fraction of outdoor pollutant concentration that penetrates indoors, i.e., is not removed by the materials that make up building envelope. If, for a compartment, the air exchange rate, the sink rate for a given pollutant, and the