Indoor air flow and smell transfer in single-family dwelling

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Introduction

Investigation and research into the so-called "sick building" phenomenon has received an increasing amount or attention during the last two decades, especially since the energy crisis of 1973. Hundreds of detailed case studies in residential or commercial envi- roments including schools, offices, home-dwellings etc., have been carried out in Europe, U.S.A., Canada and Japan. The com- plaints of the occupants take the form of different symptoms, in general they can be divided into three types: odour complaints, comfort complaints and health complaints.

There are very few results in the literature that can give definitive or clear answers for the cause of the sickness , or an effective method of preventing the problem. However, it has been suggested that the increasing concentrations of indoor air contaminants (due to tight building techniques for energy conservation), as well as the introduction of new building materials and equipment in buildings, can play an important part in the sickness syndrome.

This paper presents a case study of odour complaints by the occupants in a Swedish single family house. A relationship has been sought between the indoor air flow as well as the ventialtion and transfer of smelling sub- stance. Both the multiroom indoor air flow model MIX, see Li et al (1990), and the multi-room indoor air quality model from a previous study, see Li (1990), have been used here.

A case study

As a case study, we will choose a house located in Kristinehamn with a volume of 264 m^3, a floor area of 104.5 m^2. It was built in 1969. The floor plan, front view and one side view are shown in Figs 1, 2, 3.

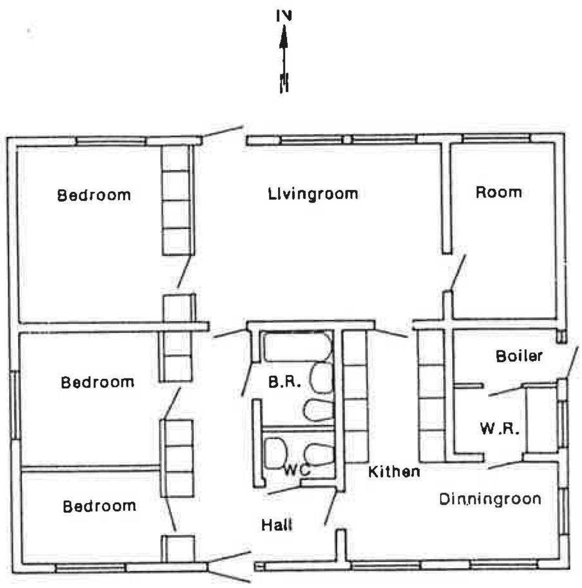

Fig. 1. The floor plan of the example house.

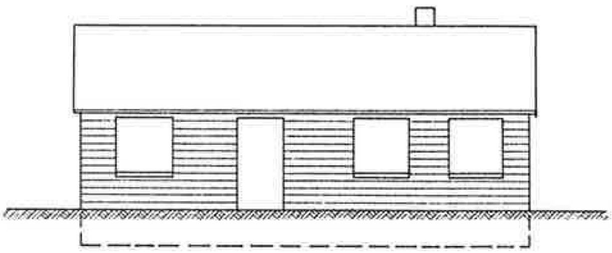

Fig. 2. The front view of the example house.

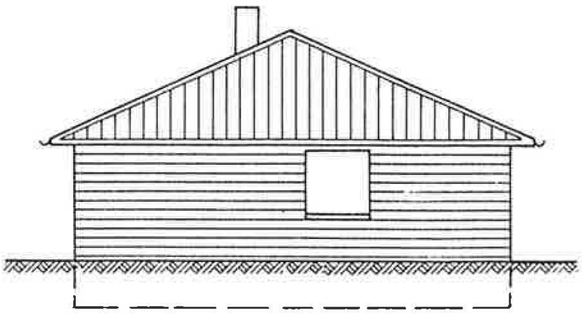

Fig. 3. The side view of the example house.

The owner of the house complained about smell problems, and they suspected that the undesirable smell came from the crawl space. Primary investigation showed that the smell may be due to high humidity and clay in the crawl space. Fig. 4 shows data measured by the local authority.

Table 1 shows the pressurization test results and an approximate measurement of the indoor pressure by the local research company in Kristinehamn.

Table 1. Result from pressurization test.

Measuring date	Leakage data Δp = 50 Pa	P_{out}-P_{in}	P_{cra}-P_{in}	Exhaust vent.
831130	740m^3/h	/	/	off, sealed
890901	/	2 Pa	1 Pa	max.180m^3/h
890901	/	1 Pa	0 Pa	min. 60m^3/h

where

p_{out} = outdoor pressure
p_{in} = indoor pressure
p_{cra} = crawl space pressure.

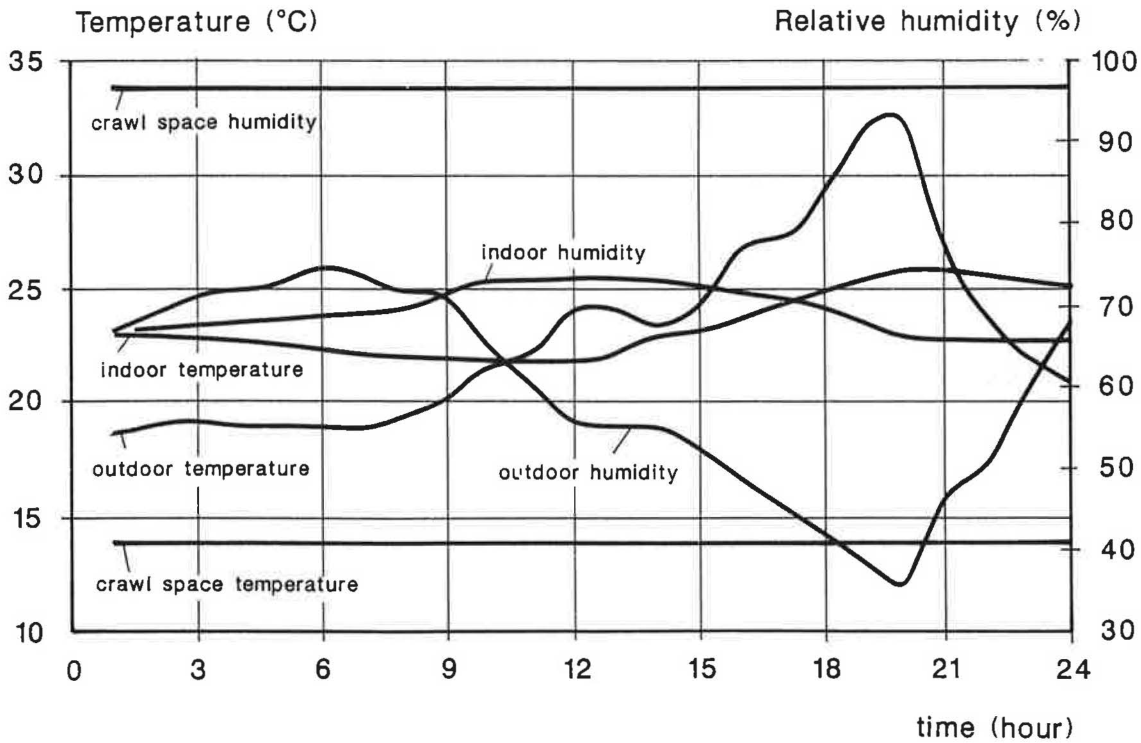

Fig. 4. Relative humidity and temperature in indoor, outdoor, and crawl space(30th, June).

An indoor underpressure existed which caused a flow of air from the outside and the the crawl space to the inside. It is very easy to understand that if there are some pollutants outdoors or in the crawl space, these could cause an indoor air quality problem.

Indoor air flow

The following k_t values were used in the calculation of the indoor air flow, where k_t is leakage coefficient (1 m^3/s at $1p_a$), see Li et al (1990). An envelope with a door or window has a k_t value of 0.00018. One without doors or windows has a value of 0.00009. For an internal wall without a door or with the door closed, k_t=0.00005. Three cases with different exhaust ventilation rates were calculated. These were ventilation off, maximum ventilation (180 m^3/h), and minimum ventilation (60 m^3/h). 0.667 of the exhaust ventilation rate is from the kitchen, 0.167 of the bathroom and 0.167 from the WC. Two kinds of wind direction, namely $\theta = 0^o$ and $\theta = 180^o$ have been used in the calculation. Ten zones (rooms) are used as shown in Fig.5. No. 10 is the crawl space. The infiltration and air flow from the crawl space to the floor are shown in Figs. 6 to 11.

There are a number of points which emerge from the analysis.

- o The air flow from the crawl space increases as the wind speed increases. When there is an exhaust ventilation, the stronger the exhaust ventilation, the greater the air flow from the crawl space.

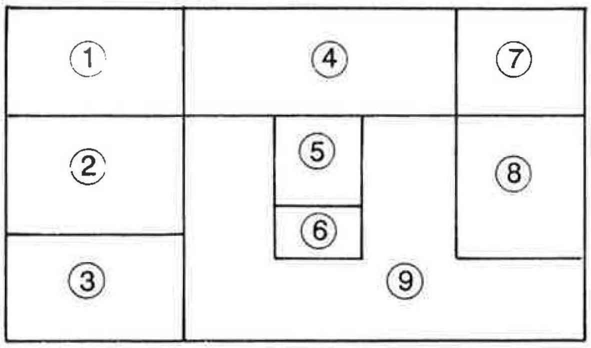

Fig. 5. Zones in the house plan.

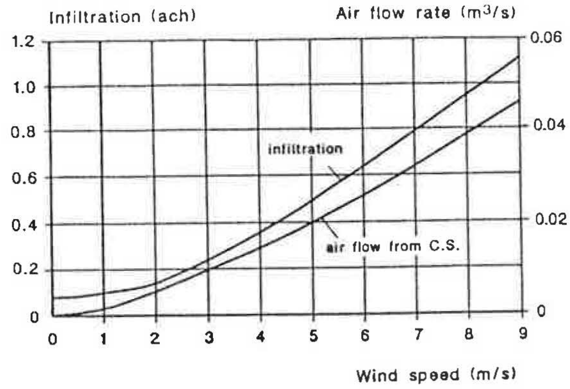

Fig. 6. The infiltration and air flow from the crawl space to rooms in one family dwelling when ventilation off, wind angle is 0^o.

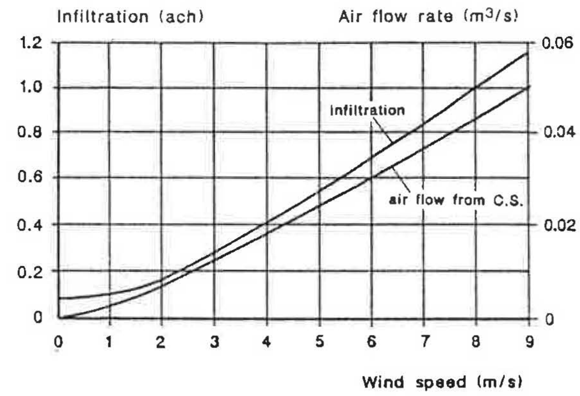

Fig. 7. The infiltration and air flow from the crawl space to rooms in one family dwelling when ventilation off, wind angle is 180^o.

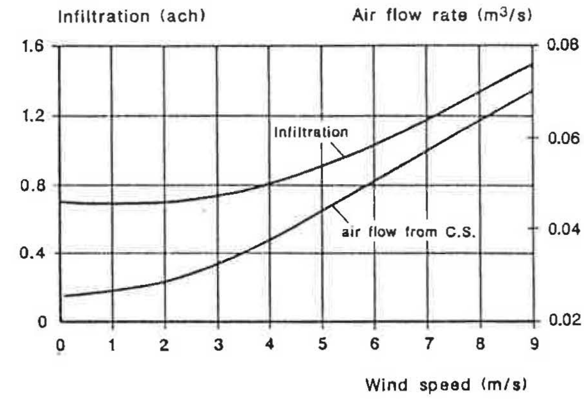

Fig. 8. The infiltration and air flow from the crawl space to rooms in one family dwelling when exhaust ventilation rate is 180 m^3/h, wind angle is 0^o.

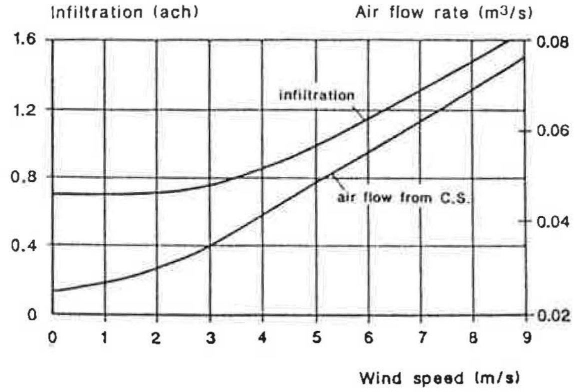

Fig. 9. The infiltration and air flow from the crawl space to rooms in one family dwelling when exhaust ventilation rate is 180 m^3/h, wind angle is 180°.

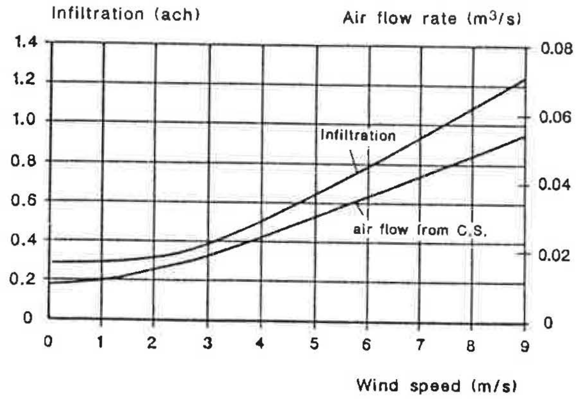

Fig. 10. The infiltration and air flow from the crawl space to rooms in one family dwelling when exhaust ventilation rate is 60 m^3/h, wind angle is 0°.

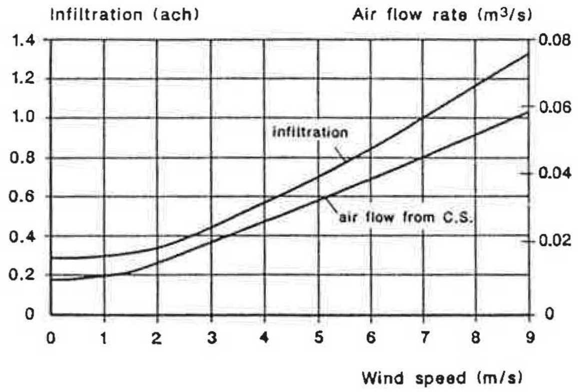

Fig. 11. The infiltration and air flow from the crawl space to rooms in one family dwelling when exhaust ventilation rate is 60 m^3/h, wind angle is 180°.

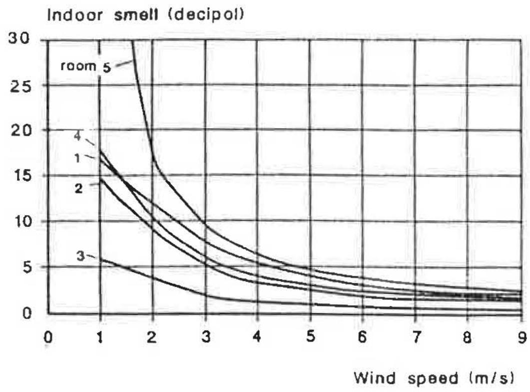

Fig. 12a. The indoor smell level due to air flow from crawl space in rooms 1 to 5, when ventilation off, wind angle is 0°.

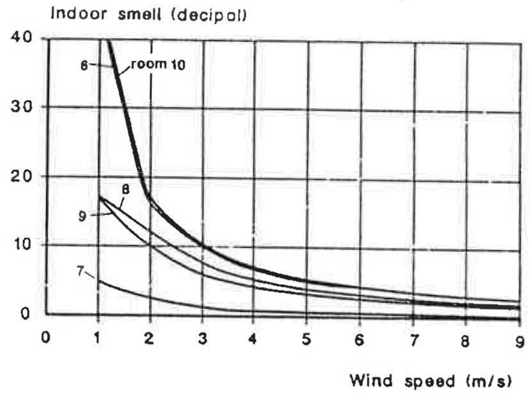

Fig. 12b. The indoor smell level due to air flow from crawl space in rooms 6 to 10, when ventilation off, wind angle is 0°.

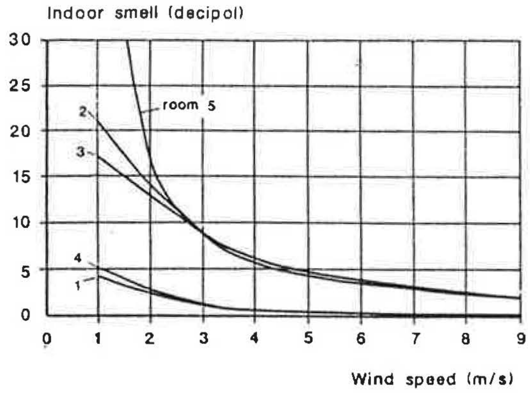

Fig. 13a. The indoor smell level due to air flow from crawl space in rooms 1 to 5, when ventilation off, wind angle is 180°.

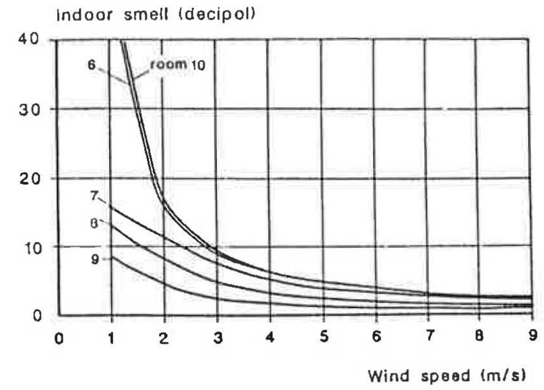

Fig. 13b. The indoor smell level due to air flow from crawl space in rooms 6 to 10, when ventilation off, wind angle is 180°.

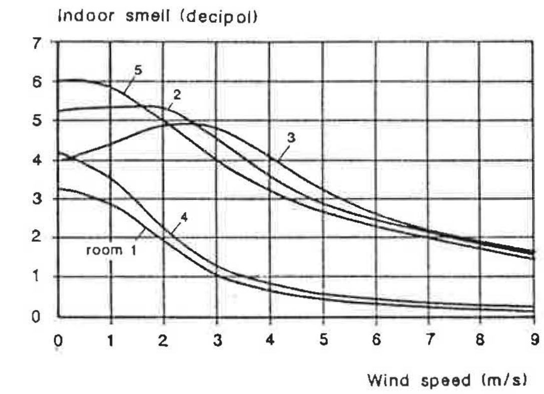

Fig. 14a. The indoor smell level due to air flow from crawl space in rooms 1 to 5, when exhaust ventilation rate is 60 m^3/h, wind angle is 0°.

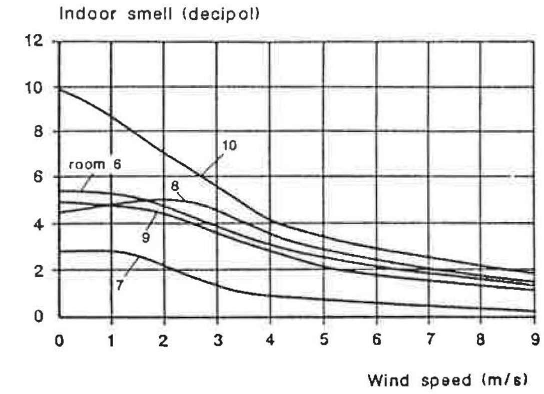

Fig. 14b. The indoor smell level due to air flow from crawl space in rooms 6 to 10, exhaust ventilation rate is 60 m^3/h, wind angle is 0°.

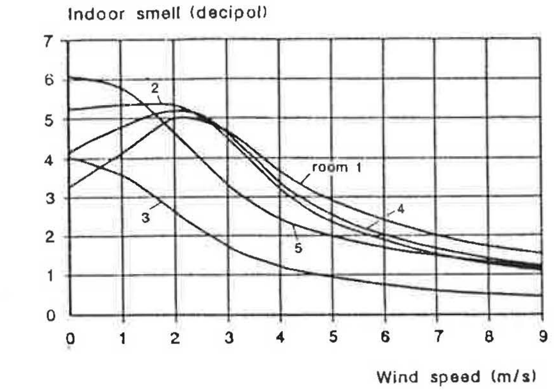

Fig. 15a. The indoor smell level due to air flow from crawl space in rooms 1 to 5, when exhaust ventilation rate is 60 m^3/h, wind angle is 180°.

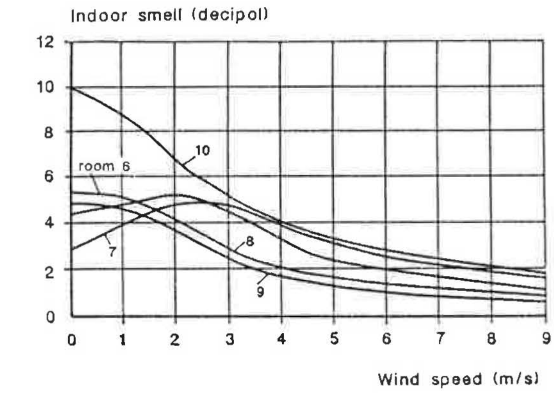

Fig. 15b. The indoor smell level due to air flow from crawl space in rooms 6 to 10, exhaust ventilation rate is 60 m^3/h, wind angle is 180°.

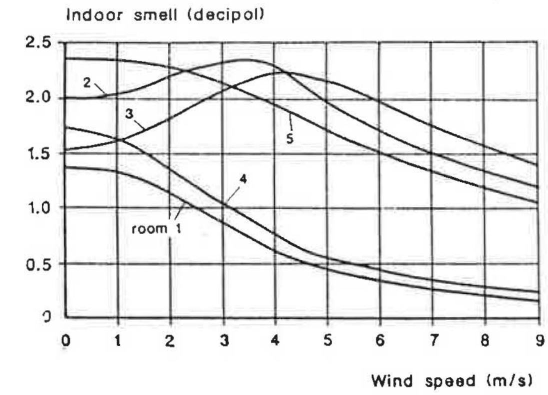

Fig. 16a. The indoor smell level due to air flow from crawl space in rooms 1 to 5, when exhaust ventilation rate is 180 m^3/h, wind angle is 0°.

- o The infiltration rate increases as the wind speed increases. When there is an exhaust ventilation, the stronger the exhaust ventilation, the greater the infiltration rate.
- o The influence of the wind direction is slight.
- o There will be a flow of air from crawl space to the floor.

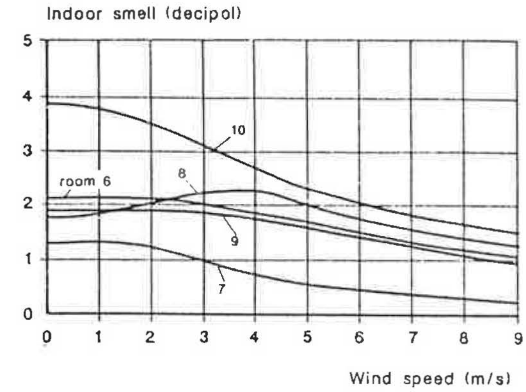

Fig. 16b. The indoor smell level due to air flow from crawl space in rooms 6 to 10, exhaust ventilation rate is 180 m^3/h, wind angle is 0^o.

Transfer of smelling substance

It is not an easy task to calculate the transfer of smelling substance from one room to another. Not only is it difficult to define the sources and sinks of the smell but there is also the difficulty of ascertaining the transportation mechanism.

It has been assumed here that the indoor air flow is the only mechanism for the smell transfer, and the smell source strength from the crawl space is constant, which is equivalent to 10 olfs. In fact, one of the assumptions for this new unit is that the smell is propotional to the substance concentration, this is probably not correct, see Peterson (1990).

Employing the multi-room indoor air quality prediction model, see Li (1990), the decipol values in every room have been calculated, and are shown in figs 12 to 17.

The points emerging from these figures are

- o Due to the air flow from the crawlspace, there is a high smell level in the rooms.
- o Ventilation is helpful in reducing the smell level.
- o The wind direction has a slight influence.

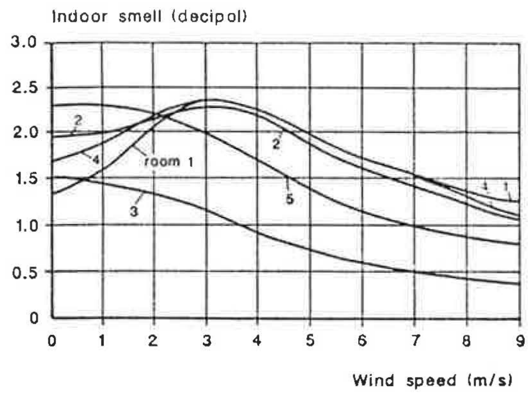

Fig. 17a. The indoor smell level due to air flow from crawl space in rooms 1 to 5, when exhaust ventilation rate is 180 m^3/h, wind angle is 180^o.

Discussion

It can be seen that indoor air flow has a great influence on indoor smell transfer. From the point of view of improving the indoor environment, an effort to choose the correct indoor air flow should be made. In the case study here, for example, an exhaust fan could be installed in the crawl space, or the tightness of the floor between the indoors and the crawl space could be improved.

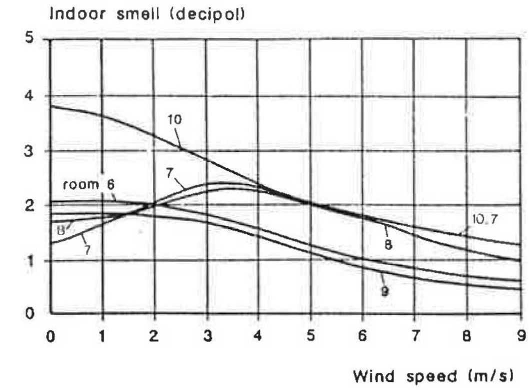

Fig. 17b. The indoor smell level due to air flow from crawl space in rooms 6 to 10, exhaust ventilation rate is 180 m^3/h, wind angle is 180^o.

This paper only attempts to explain the odour complaints from the occupants of this house. It does not lead to a clear solution of the sick building problem, which is a much more complex problem. However, it should be highlighted that not only a reduction in infiltration and ventilation, but also an unsuitable air flow direction can cause undesirable concentration of indoor pollutants.

References

Li, Y. and Peterson, F.: The modelling of multi-room air flow and its application to exhaust ventilation analysis. Climate and Building, No. 2, Dept. of Heating and Ventilation, the Royal Institute of Technology, Stockholm, 1990.

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