Health performance indicators of housing

E. Hasselaar

OTB Research Institute for Housing, Urban and Mobility Studies, Delft University of Technology, The Netherlands

ABSTRACT
Healthy housing strategies tend to focus on good comfort and on avoiding specific health risk agents. These agents are generated by building features and occupancy and may come from both indoor and outdoor environments. This research project focuses on building features and the impact they have on the indoor environment. The interaction between the building and occupancy patterns is studied. This paper describes the selection of the smallest set of indicators that allows a simple but effective evaluation procedure of the health performance of housing. The indicators are the markers of the main health risk agents in the house: mould, house dust mite, radiation, *Legionella pneumophila*, aerosols, noise and injuries. A health performance evaluation tool is being designed on the basis of these indicators. The tool can support the design of housing retrofits and maintenance policy in the housing stock. The research connects health risk and building quality assessment and is situated in the field of sustainable building.

INDEX TERMS
Housing; Performance indicators; Building features; Life style

INTRODUCTION
The environmental health risks of housing re-emerges as a research and design topic in countries that have improved energy standards and introduced new products to increase the sustainable quality of housing. Conflicts arise when the ventilation capacity is reduced for the sake of energy conservation, when solar gain in well-insulated buildings causes overheating and when mechanical systems are not used properly because of their noise level. Domestic water systems can become a source of bacterial contamination. Some new materials like cellulose-based paint and adobe surfaces provide better nourishment for mould than the traditional materials. Sustainable building will also improve the health performance: thermal and acoustical comfort increases with better insulation and the house is more likely to support ecological life styles. Much information is available on environmental parameters of health, but this information is not related to specific building features and life styles. In one of every four to five houses in northern European countries, an occupant has respiratory problems, while structural problems that cause indoor air pollution are not being addressed. The malfunctioning of the ventilation system, mould caused by condensation on heat barriers, emissions from the crawl space and other health risk agents are of minor concern to housing professionals as they are not aware of the health performance of the housing stock.

This paper explains one aspect of the design of a health performance assessment tool that supports housing professionals in healthy housing policies. This aspect is the selection of indicators that point at health risk agents and that are the markers of health performance. In general, an indicator is a sign or marker that points to a condition to be measured, in order to evaluate specific qualities (adapted from Cole *et al*., 1998). The health performance of a house can be measured and compared by using performance indicators. In this study the indicators are building properties, selected from a large variety of building details, services and features that have the power to represent the health risk agents of a house.

The health potential of any house is disturbed by health risks. These risks are caused by agents, while the impact on the occupant depends on the exposure. Agents are generated under the influence of parameters like humidity or noise. The key agents in the house are mite, mould, radiation, aerosols, VOCs, lead, contaminated drinking water, noise and disturbance.

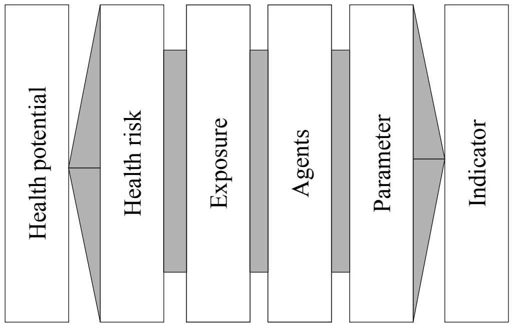

Figure 1 The path from health potential to indicators.

The research question is: What is the smallest set of indicators that supports a simple but effective evaluation procedure of the health performance of housing?

RESEARCH METHODS

The research started with inspection of houses, a total of 500 in 8 years. The inspections of the first period (n = 265) were problem oriented and focused on analysis of complaints by tenants. In each problem situation a randomly chosen house was inspected and its occupants interviewed as well. This procedure provided better insight in the relation between life style and building features. The interview and inspection protocol was improved step by step and adapted to the purpose of analysing cause and effect (Hasselaar, 2001). The indicators emerged from this inspection protocol. Discussion with housing professionals and other experts (including lawyers) resulted in refinement of the indicators. To support the selection of the smallest set possible, model studies are being performed for house dust mite and aerosols. These models include both technical building features and life styles.

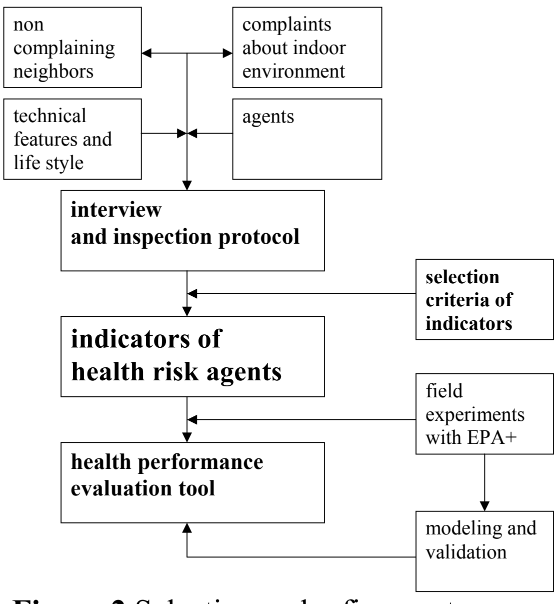

Figure 2 Selection and refinement process of indicators.

RESEARCH RESULTS

Many conflicts about poor indoor environments occur because users (tenants) and home owners or housing professionals have a different opinion and perception about the meaning of technical features and life styles. For instance, in 75% of Dutch rental houses with mould problems the cause is related to construction and material properties, but the home owners connect the problem with poor ventilation and high moisture production by the tenants. Many houses do not permit a large and free choice of life styles and the 'other party' is blamed for problems. While the effect of occupancy styles seems to be overestimated by housing professionals, we can, however, distinguish certain styles that conflict with building features and increase environmental health risks.

From the interviews with tenants, three occupancy styles can be isolated:

- *Traditional:* two or more persons share a household, and at least one person spends much time at home, being active in and around the house.
- *Absentee:* the occupant(s) work or study elsewhere, frequently go out at night or in the weekends and use the house like a hotel—for evening relaxation and sleep.
- *Cocooner:* much time is spent indoors and in isolation from the environment outside—the windows and doors are closed.

The combination of life style with perception results in five risk levels (Table 1). The risk levels of users who are unaware or unable to control the indoor environment (especially ventilation) are highest for senior and very young cocooners.

Table 1 Risk levels defined by occupancy, perception and behaviour

Occupancy style	Perception	Behaviour	Risk level
Traditional	Aware and adaptive	1. Good ventilation, cleaning, no smoking	Very low
	Unaware or non-adaptive	2. Low ventilation, emission sources	Low
Absentee	Aware and adaptive	3. Control depends on features of house	Feature dependent
	Unaware or non-adaptive	4. Lack of control on indoor environment	High
Cocooner	Aware and adaptive	5. Emission sources, feature dependent	Feature dependent
	Unaware or non adaptive	6. High emissions, low control	Very high

Technical Building Features

The interview and inspection protocol resulted in a shortlist of features of a building that provide information on the generation of agents. Table 2 presents the inspection and interview items and they constitute a preliminary set of indicators

Table 2 Inspection items and interview subjects

Cluster	Inspection item	Interview item	Agent to be assessed
Heating system	Heat supply for bedroom and living room	Temperature setting, day–night fluctuation, passive heating	House dust mite, mould
Water system	Stagnant buffer, cold and hot temperature, non-used taps	Increased temperature of cold water	*Legionella pneumophila*
Ventilation system	Size, location and control of inlet openings	Use of inlet openings	Air quality, draught, noise from outside
	Exhaust system, type and location of fan, dampers	Set-points, fan age, cleaning frequency, effectiveness	Air quality, noise from fan
	Circulation: size of openings in/under doors or walls	User pattern, air speeds	Air quality
Construction quality	Crawl space	—	Radon, moisture
	Sealing floor and walls	Central heating pipes	Radon, moisture
	Infiltration of air	—	Air quality
	Insulation	Temperature bedrooms / carpet	House dust mite
	Heat barriers	Visible mould	Mould
	Construction materials	—	Particle emissions, radon
	Surface materials	Visible mould	Mould, emission
	Infiltration of moisture	Visible moisture	Mould, house dust mite
	Sound insulation	Noise and nuisance	Stress, no use of services
Functional quality	Location of kitchen	Period with smell of cooking	Aerosols
	Orientation of windows		Noise, passive heating, excessive heat
	Location of shower	Use of shower, condensation	Mould, house dust mite
	Location laundry drying	Frequency of washing, drying	Aerosols, moisture
	Stairs, slope, curves	—	Injury
Cleanliness	Cleaning, dust build-up	Dustiness, mould eradication	Aerosols, mould
Outdoor environment	Water level	Flooding of crawl space	Mould, house dust mite
	Outside air quality	Ventilation restrictions	Smell, air quality
	Traffic situation	Playground for children, noise	Stress, air quality
	Social atmosphere	Social contact, burglar impact on use of ventilation openings	Stress, air quality
Occupancy	Pets, hairy, feathers	Where allowed in house	Air quality
Behaviour		Special activities	Air quality, noise

The items in Table 2 provide a more detailed representation of Figure 1 (see Figure 3). The next step is to relate each indicator-cluster to specific agents. A set of 26 indicators has been defined that support the assessment of the nine agents. Inspection on the basis of these indicators is expected to facilitate health performance evaluation by building and maintenance professionals, but does not replace sophisticated assessment protocols.

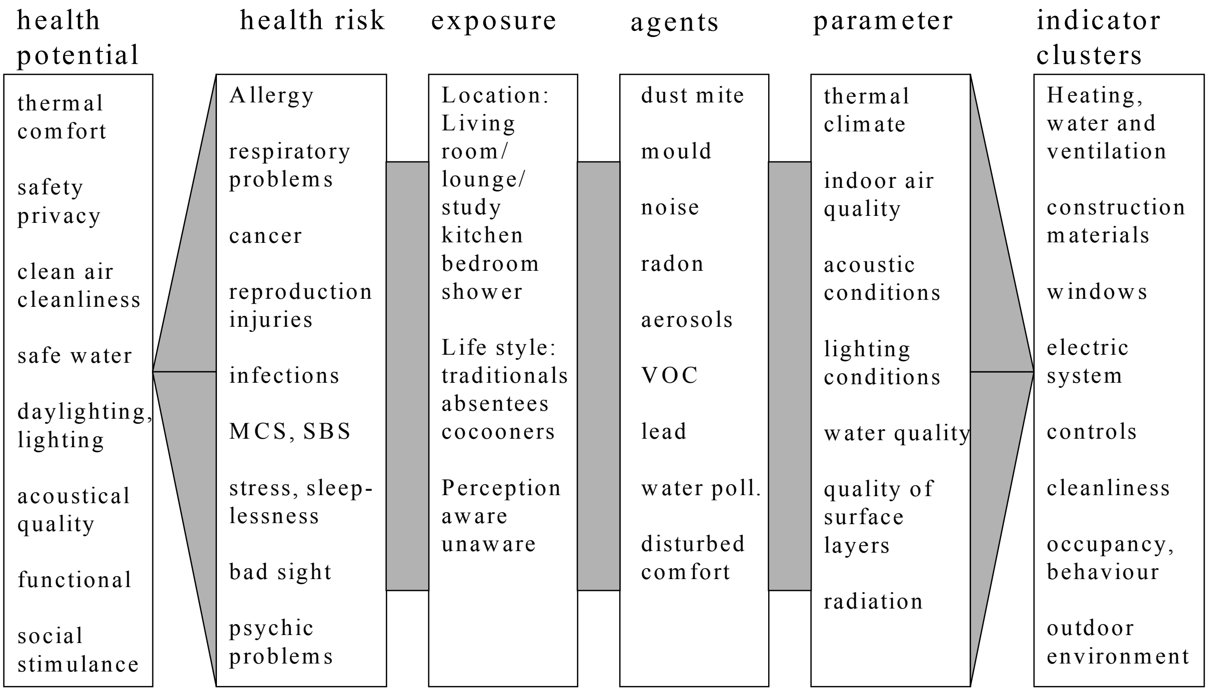

Figure 3 The link between health potential and item indicators.

The 26 indicators can be inspected by following a protocol with 169 items. The set is the basis for a health performance evaluation tool.

Figure 4 presents the smallest set of indicators. Indicators of indoor air are dominant, with noise as the second ‘agent’. Mould growth and aerosols have many indicators. The set of 26 indicators results in a protocol with 169 inspection items and questions.

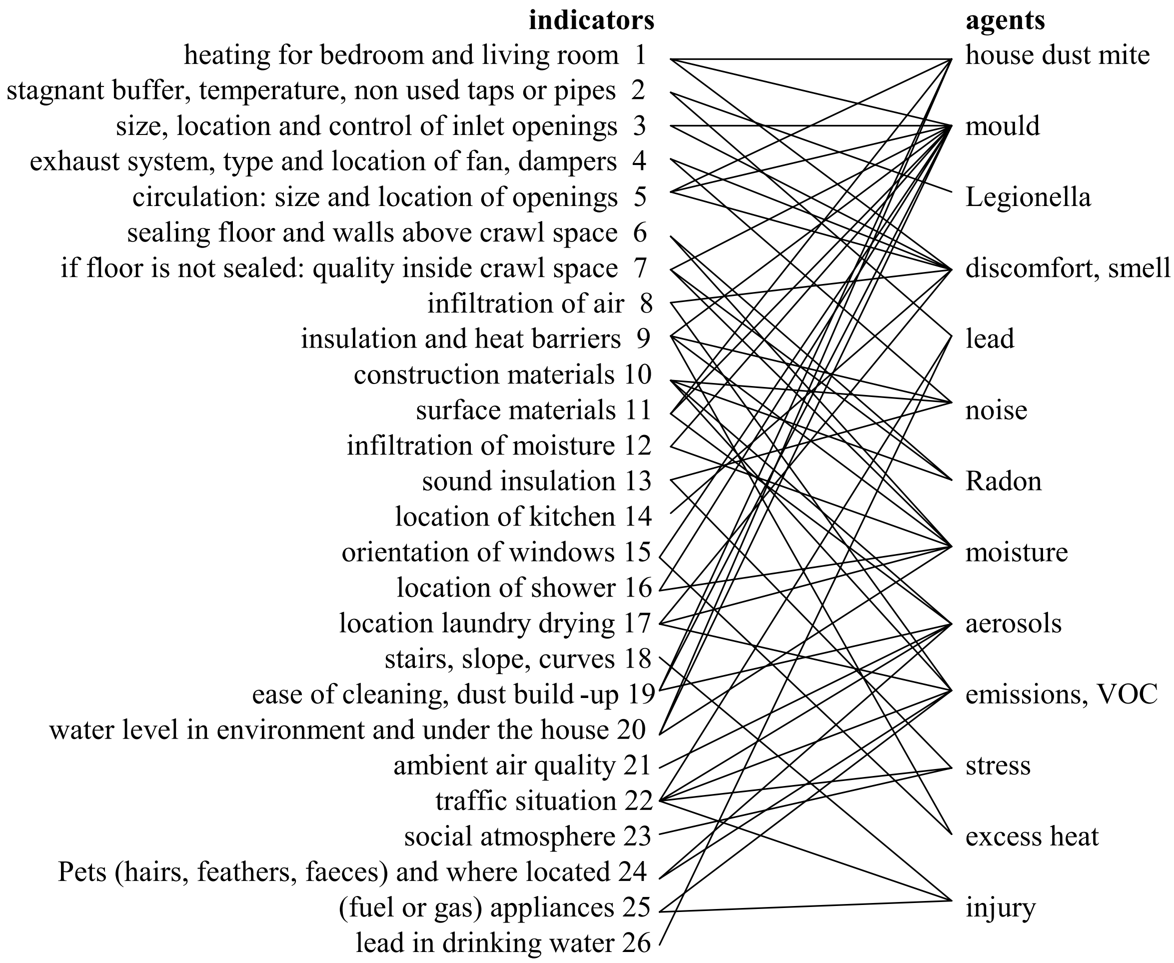

Figure 4 Indicators and agents.

DISCUSSION

Health performance evaluation of buildings represents a complex field and the lack of practical experience by housing professionals limits the concern for healthy housing. Denial or trial and error can be recognized as strategies of home owners in dealing with environmental problems. Housing associations introduce performance evaluation and use the results to measure the quality of the organization, often with focus on their customers. The housing associations develop new tools for strategic stock maintenance, in which market potential, financial position and neighbourhood quality are the key factors for new policies. They do not measure the sustainable quality or the health status of the housing stock. The selection of indicators of health risk agents can be seen as a step towards better integration of health performance in housing maintenance. The next step is to develop instruments that can be integrated in tools already used by housing professionals.

The set of indicators resulted from work in the field and from involvement in litigation procedures and mediation projects. The selection process is qualitative and action oriented, and the present issues in housing quality may have biased the results. Work on the validation of models on the relation between indicators and health must be continued. The house dust mite model is being validated on the basis of 115 dust samples. The aerosol model will be broken up into different parts. Studies on deposition have been executed and for this purpose a test chamber has been built. The results will be integrated in studies in three full-scale test houses. The health performance evaluation tool is expected to be available in mid-2004.

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