Workshop 5 - The Residential Context of Health

Approaches to Health Assessment Related to Housing

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Abstract
This research had the purpose of providing more information about possible approaches and indicators to measure indoor health in relation to housing. In researches related with health and some Life Cycle Assessment (LCA) databases, the model used for health assessment is the “Impact Pathway Analysis” adopted from Risk Assessment. It has the objective of expressing possible effects to human health in damage indicators, such as DALYs (Disability-Adjusted Life Years). Calculating damage in the indoor environment implies having knowledge about the rate of emission of the substances, human exposure to the substances and the effect of the pollutants on humans. The sources and rates of toxic substances, the type of exposure, and the safeguard subjects (i.e. population of concern) must be defined. In life cycle assessment, all health effects during the whole life cycle of the house are summed up, which is very inconvenient when a risk analysis is needed. It appears that the approach to be followed should be mainly related with the scope of the assessment, for which three possible approaches were identified; a) Buildings physical characteristics approach, b) Building use approach, that includes the effects of the building and of occupants activities c) Life Cycle of Building Effects, which considers the effects of building and users activities during the whole life cycle of the building affecting therefore a broader population.

1. Introduction
The effects on health produced by indoor conditions in buildings have taken more importance in the recent past (Baechler et al. 1991, Hoskins 2003, Rollins and Swift 1997, WHO 1979, WHO 1983, WHO 2004). One of the issues of more concern nowadays is the quality of life of people. Part of the factors affecting quality of life is related with health. Improving building conditions in order to provide a healthier life to the population should therefore be a main concern. Several researches on healthy housing and LCA have been conducted related to health damages produced by materials, combustion products, respirable particles and indoor climate characteristics. The effects of and exposure to a great variety of emissions have been studied and documented (WHO 1996, WHO 1992, WHO 1991, WHO 1987, Müller-Wenk 2004, Menetrez and Foarde 2003). These efforts to quantify such effects are visible in Life Cycle Assessment methodologies, databases and models (Goedkoop and Spriensma 1999, Goedkoop et al. 2004a-b, Jolliet et al. 2003, Meijer et al. 2005a-b, Huang et al. 2004). Nevertheless, there is a lack of integration between the different sources and stressors that affect human health indoors and the methodologies and approaches tend to vary according to the vision of the research (Muller-Wenk R. 2004; Meijer A. et. al. 2005a+b; Goedkoop M. et. al. 2004).

This research aims to study the methodologies and approaches followed nowadays in health assessment in order to select the most suitable indicators and approaches when health assessment is conducted in relation to housing. First, human health assessment methods related with damage assessment are explained. Second, the factors possibly affecting human health in buildings are outlined. The interactions between these factors are modeled. Third, ways of combining general human health assessment methods with the specific case of housing are studied. Finally, conclusions are drawn about the possible approaches.

2. Health in the Indoor Environment
In this research, assessing health in the indoor environment means quantifying the damage to human health produced by the direct interaction of humans with indoor stressors. In this section, concepts related with health assessment are presented. First, the population of concern is defined. Second, the difference between types of damages and their implications in health assessment is explained. At the end, the method to follow in health assessment is presented.

2.1 Safeguard subject
The first step of damage assessment is to define the safeguard subject. The safeguard subject is the population on which is conducted the study. In the case of human health, the safeguard subjects are defined as human beings. Nevertheless, there are more considerations to be taken into account. These considerations rely on the goal and scope of the research. Depending of the type of study, the considered population characteristics within the research will vary. Factors such as gender, age, socio-economical level, education and other social conditions could be taken into account depending on the goal of the assessment.

The part of the population to be studied has to be clearly defined in order to establish the indicator and method to be used. This depends on the exposure scale (part of the population) to be measured and it is strongly linked to the scope and objective of the assessment. For instance global population could be used in the case of substance emissions to the environment, and local population for single industry impact assessment. For building assessment, only the occupants of the dwelling or building could be considered.
2.2 Known and unknown damages

The second step of damage assessment is to categorize the types of damages (known or unknown) to be studied with the purpose of determining the method to be used. This helps to determine the type of damage that can be assessed for each kind of health impact.

Hofstetter (1998) determines 2 types of damages: known damage and unknown damage. Known damage refers to those effects that can be measurable and for which there is enough data for making the assessment. Unknown damage refers to the effect for which there is not enough information available and which effects are not completely known; therefore, the attribution of a quantity of damage to them is not possible.

Known and unknown damage are important concepts within human health assessment. Nowadays there are some substances that are considered to be possibly toxic to humans but there is no real proof that they are in fact detrimental to health. This is because tests in humans are not available and some effects are only visible a long time after the exposure (e.g. some carcinogenic substances).

The measurability of effect in human health depends on the viewpoint of the valuating groups; for certain groups an impact could be only considered damaging when there is proof that it has direct repercussions in human health, meanwhile for another group a simple hypothesis of damage could be included within the known damage category (precautionary principle).

The classification of damage in known and unknown can help us to determine the type of indicators and safeguard subject. Damage assessment using endpoints indicators (e.g. DALYs) and human health as safeguard subject is only possible for known damage. Therefore, for the purpose of studying damage to health, only known damages can be considered, which may limit the scope on an assessment.

2.3 Impact Pathway Analysis

Known damages can be measured using the impact-pathway-analysis method (Hofstetter, 1998). This method consists of: fate and exposure analysis, effect analysis and damage analysis. Figure 1 presents the steps for impact-pathway analysis.

The first step is the inventory analysis. In this part, defining the safeguard subjects and endpoint is important. The endpoints are the effects shown by the safeguard subjects due to the exposure to determined emission. The output of this phase is the emission to be analyzed.

The next step is the fate analysis (distribution of substances into various environmental compartments) and exposure analysis. In this phase, the relationship between emissions to different compartments and the exposure of the occupants to a contamination are modeled; this is quantified in concentration of pollutants in a specific compartment (using the same procedure for each compartment) and/or the quantity of pollutants that enter the organisms of the subject per emission unit. Factors related with with indoor environment that affect this phase are meteorological conditions, conditions of release, emission patterns and variation of background concentration for fate analysis, and places and time where people breathe for exposure analysis.

In the effect analysis, the dose-response relationships are used in order to quantify the expected effect caused by the exposure to the emission. The dose-response relationships are determined through toxicological tests and epidemiological studies. The result of this phase is the health effects per intake unit.

Damage analysis consists of linking the health effects to an index for the damage to human health. The severity of damage of the health effects is determined on preferences and values of health states (e.g. the relative severity of a type of cancer in comparison with the loose of a limb).

Figure 1 The general set-up of the impact pathway analysis (Hofstetter, 1998)

2.4 Methods to measure health damage

Human toxicity and human health are the two characterization factors included in current health assessment.
2.4.1 Human toxicity

Human toxicity measures the quantity of toxic substances released to the environment that can cause adverse effects on humans. It is mainly expressed in substances emissions (Heijungs and Goedkoop). This approach eliminates or diminishes the uncertainty due to the relationship between toxicity and health effect, (Jolliet et al, 2003). Human toxicity is calculated by taking into account fate, exposure and effect per unit mass of emission (see figure 1).

This category has the characteristic of being expressed in midpoints (substances emissions). Midpoints are indicators located in the cause-effect chain within the life cycle inventory (Heijungs and Goedkoop). Examples of midpoint are respiratory effects, global warming, and ozone layer depletion.

2.4.2 Damage to human health

Damage to human health is not limited only to human toxicity. It can refer to all measurable health effects, such as annoyance due to noise, carcinogenic effects, and respiratory diseases. Human health damage assessment result in indicators with often higher uncertainty than indicators based on the midpoint approach (Jolliet et al, 2003). The most common method to follow is the impact pathway analysis (see figure 1).

2.5 Indicators for health

Indicators provide useful and relevant information that reflects the objectives and viewpoint of the decisionmaker. The choice of an indicator depends on the level of accuracy of the dose-response relationship and on the available information on it. Indicators can be differentiated by their final output; these classify indicators in Potency-based and Severity-based indicators (Jolliet et. al. 2002, Krewit et. al. 2003).

2.5.1 Potency-based indicators

Potency-based indicators provide a measure of the potential human damages caused by emissions. It includes all substances, media and effects to the safeguard subject (e.g. ecosystems). They are used as a prior step to severity indicators or as simple indicators, especially for regulation purposes. These indicators lack the final step of damage assessment where the effects are expressed on human damage indicators. A characteristic of these indicators is that they are expressed in equivalence factors (e.g. Benzene-e/kg emissions, Toluene-e/kg emissions). These indicators are mostly used in the human toxicity approach.

2.5.2 Severity based indicators

Severity based indicators are related to endpoints directly attributable to human health effects. Their main characteristic is that they express a societal concern. They are considered to be easier to understand, and easier to use for decision-making, but they have a higher uncertainty. These indicators are in accordance with the human health approach in the impact pathway analysis method. A widely used severity-based indicator is DALY/kg emission.

The concept of DALYs takes into account the years lost by premature death and, in case of illness, the physical impairment due to illness with its duration. The method for calculating DALYs allows data aggregation, which can provide information about the effect of a certain disease in a specific group of the population (e.g. DALYs due to combustion products in developing countries WHO 2004b); this is useful to identify major health problems and their main causes (Murray and Lopez, 1994,1997; Murray et al. 1994, 1997).

The aggregating characteristics of the DALYs make them suitable for being used as indicators in LCA with few modifications. These modifications are related especially with social weighting factors. Hofstetter (1998) adjusted the DALY methodology for use with LCA in his individualist cultural perspective (Hofstetter, 1998) by removing two discounting rates: age weighting and future DALYs. In the original DALY concept, age weighting is applied because some ages are considered to be more valuable for society than others (Murray, 1994). Future DALYs discount is made because for present generations, the damage produced in the future is less valuable (Murray, 1994).

2.6 Implications for healthy housing

In order to express damage on human health like a societal concern, it must be defined with severity-based indicators through an endpoint approach. DALYs indicator has been accepted in LCA methodologies (Goedkoop and Spriensma, 1999) due to its properties for damage aggregation.

Nevertheless, DALYs have characteristics that may be inconvenient in their application for healthy housing assessment. DALY is an indicator created to measure the burden of disease in specific countries or in the world. Furthermore, the DALY methodology considers only the negative health effects of houses. For this reason, positive effects of an object or activity are not considered. When applied to housing, the use of DALYs could lead to
problems because the positive characteristics (e.g. thermal properties, noise isolation or protection) of certain materials would not be considered.

### 3 Sources and stressors affecting human health in relation to buildings and housing

The five steps of the Impact Pathway Analysis are defined in section 2 for health assessment: inventory analysis, rate and exposure analysis, effects analysis, and damage analysis. In this section, an inventory of the sources and stressors is described, considering the interrelation among the different factors (e.g. building characteristics human activities) that tend to affect the phases of the Impact Pathway Analysis.

#### 3.1 Interrelation of Factors

The identification of interrelated factors is needed in order to provide an overview of the way the occupants are exposed to toxic compounds. Figure 2 shows the interrelated factors that affect human health.

The variables that create the conditions for toxic emissions can be classified as building characteristics, activity related and outdoor sources. These variables are: building physics, HVACs, material type, energy type, behavior and location.

- Building physics refers to the characteristics of the building related with shape and function, such as layout, orientation, insulation, disposition of the spaces, size and functioning of the windows, etc.
- HVAC refers to the presence of heating, ventilation and artificial climate systems and their functioning.
- Material types and characteristics are related to emissions.
- Energy type is related to toxic emissions.
- Behavior refers to the use of the building by their occupants, size of the exposed population and time of exposure.
- Location characteristics refer to outdoor air pollution and noise.

Each variable determines one or more specific stages in the analysis pathway of human health damage. The stages considered in this research are: sources, stressors, fate and exposure factor, effect, and damage. The use of these stages varies according with the emission source to be analyzed due mainly to differences in knowledge about the cause-effect relationship of some emissions.

![Figure 2 Interaction of factors affecting human health in the indoor environment](image)

Figure 2 shows three types of sources: building related (materials, building physics, and HVACs), activity related (behavior and lifestyle, smoking and fuel use for cooking), and outdoor sources (traffic and neighbors). Stressors are shown in the third column of the figure. Each stressor is caused by different sources, and each source causes more than one stressor. Within building related sources, materials and physical characteristics of the building determine materials’ emissions; HVACs and building physics determine the indoor climate. In the activity related category, smoking behavior and the fuel used for cooking causes combustion products. In addition, toxic compounds are related with behavior and lifestyle of the occupants. Biogenic particles are cause by both building and activity related sources, such as materials, physics, HVACs, and behavior and lifestyle. The stressors produced by outdoor sources are noise, which is caused by traffic; and air pollution caused by nearby sources (e.g. industries). There are three main factors that affect the exposure to the stressor, which are finishes of the building, materials and ventilation behavior. Finishes can affect the emissions from materials positively or negatively; noise from outdoor sources can be diminished with acoustic materials, and ventilation behavior influences all stressor produced by indoor sources (building and activity related). Table 1 shows how health effects relate to the various stressors.
### Building related

<table>
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<tr>
<th>VOCs</th>
<th>Carcinogens</th>
<th>Respiratory illnesses</th>
<th>Central nervous system</th>
<th>Irritants</th>
<th>Cardiovascular system</th>
<th>Behavioral</th>
<th>Bone and renal</th>
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<td>CO</td>
<td>NOx</td>
<td>SO2</td>
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</table>

Table 1. Health effects and stressors in the indoor environment
Sources: Baechler et al. 1991, Hoskins 2003

### 3.2 Building related

The first category of sources affecting human health in buildings is related with effects produced by the building characteristics. Most of these effects can be decreased by better design and good maintenance of buildings. There are two types of building-related factors that affect human health: emissions from materials and indoor climate.
3.2.1 Emissions from materials
Some materials emit toxic compounds. These emissions take place during the whole lifetime of the materials or they can be emitted only during a determined stage such as after the application of the material (e.g. glues or paintings) or during demolition (e.g. asbestos). Four types of emissions from materials can be distinguished: VOCs (Volatile Organic Compounds), gamma radiation, radon, and particulate matter (Meijer, 2005a, 2005b).

3.2.2 Indoor climate
Indoor climate is related to building physics, to HVAC (heating, ventilation and air conditioning) equipment, behavior (e.g. turning on/off ventilation), and to the perception of discomfort of occupants (noise, temperature and humidity).

3.3 Activity related
The second category of sources of stressors affecting human health is related with human behavior and activities, such as cooking, smoking, cleaning and having pets. Two main factors can be distinguished: combustion products, viable particles, and toxic compounds.

3.3.1 Combustion products
Substances emitted by combustion processes cause mainly respiratory problems. These substances can be classified in VOCs, tobacco substances, carbon monoxide, sulphur dioxide, nitrogen oxides and PM10. (WHO 1992).

3.3.2 Biogenic particles
Living organisms and their by-products, and organic dust are among the factors that contribute the most to these particles. Viable particles affect mainly the respiratory system. They are mainly caused by interaction between indoor and outdoor conditions (Menetrez and Foarde, 2003) and therefore to activities performed by the occupants of the building. Both building characteristics and human behavior contributes to viable particles (WHO, 1992). Nevertheless, they are considered inside the activity category because that they tend to appear only by specific use of the building (e.g. having pets or taking a lot of showers).

3.3.3 Toxic Compounds
Some behavior related activities tend to produce toxic compounds that usually are not found in housing. These activities are certain hobbies (e.g. pottery, painting), cleaning activities, and some kind of furniture and finishes (Bruinen de Bruin et. al. 2005; Yu C, and Crump D. 1998; Wiglusl et. al. 2002).

3.4 Outdoor sources
Part of the noise and contaminants influencing human health originates from outdoor sources. These factors can be addressed with two purposes. The first one is related with urban or neighborhood health assessment. The aim of the second one is to determine which building characteristics increase or decrease the effects of such factors (e.g. filters for air pollution and acoustic insulation for noise). Even though damage caused by outdoor sources is closely related with type of materials, building physics and HVACs, this damage cannot be accounted to the building, because these characteristics also help to minimize the damage caused by outdoor sources.

3.4.1 Noise
Noise is related mainly to transport, but other sources such as neighbors, factories or other noisy sites can have influence in noise-related annoyance or illness (Müller-Wenk, 2001).

3.4.2 Air pollution
VOCs and respirable matter in the indoor environment can originate from outdoor sources such as road traffic or industrial plants. The contribution of these sources to the indoor concentration can be decreased by lowering the ventilation rate. It is considered that humans spend most of the time indoors; therefore, indoor air quality has a larger effect on human health than outdoor air quality. Nevertheless, ventilation allows outdoor pollutants to the indoor environment. Therefore, in current LCA models (e.g. multibox model) indoor concentration is considered to be equal to outdoor concentrations.

4 Approaches to Human Health Damages Related to Buildings
The way to assess human health depends on the objective of the assessment, which determines the characteristics of the approach. The variables that characterize an approach were identified in this research as:
- Scope
- Exposed population considered
- Positive and Negative Effects
4.1 Scope
The scope of an approach is determined by the objective of the assessment. In the case of buildings, three types of scope have been identified: indoor exposure, effects on human health produced by the building, and effects on human health produced by the life cycle of the building.

4.1.1 Building Physical Characteristics Approach
This building physical characteristics approach focuses on the human health effects caused exclusively by building’s physical characteristics during the use phase of the building. It takes into account both indoor and outdoor sources. The endpoint in this approach is human health damage produced by building’s physical characteristics. The factors considered in this approach are:

- Emissions of materials
- Outdoor air pollution entering the indoor environment
- Noise
- Indoor climate

Figure 3. Building Physical Characteristics Approach

Outdoor related emissions (e.g. noise and air pollution) can be considered into this approach when they are related with the characteristics or conditions of the building such as ventilation for air pollution and acoustic insulation for noise.

4.1.2 Use Phase Approach
The second approach takes into account the effects on human health caused by both the buildings physical characteristics and the life style of users. The endpoint of this approach is human damage produced by the building and the activities related to its use. The factors considered in this approach are:

- Emissions of materials
- Viable particles
- Indoor climate
- Outdoor air pollution that flows to the indoor environment
- Noise
- Combustion products

Figure 4. Effects of Building Use Approach

4.1.3 Life Cycle Approach
In the life cycle approach, not only the physical characteristics of the building and the building use are taken into account, but also the additional effects caused by other activities during the life cycle of the building. These additional effects are the effects on total population and production/construction workers during the extraction of raw materials and the production of materials and components, and during the construction, maintenance and demolition activities. The endpoint of this approach is the human damage produced by the building and the activities related with its life cycle. The factors considered in this approach can be differentiated depending on the safeguard subject:

- Total population of a determined area (occupant of the building, neighbors, district)
- Workers in the area of extraction of raw materials, production of building components and construction activities
- Impacts to global population related with extraction, production and construction activities

Figure 5. Effects of Life Cycle of Building Approach
This approach is related to LCA with the difference of taking only into account the direct effects on human health (i.e. direct exposure). Life Cycle Assessment is a method for analysing the environmental burden of products (goods and services) from cradle to grave, including extraction of raw materials, production of materials, product parts and products, and discarding of them by recycling, reuse, or final disposal. LCA is defined as the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle (Cole et al. 2005, Forsberg and Malmborg, 2004, Guinée 2002, Howard 2005, Klunder and Van Nunen 2003, Treolar et al. 2000). The product system is the total system of processes needed for the product.

Life Cycle Assessment merges quantitative objective analysis and subjective decisions (Hertwich et al. 2000). Subjective decisions are taken when the relative severity of the different environmental impacts is weighted according to social preferences. The social factors influencing health are, however, generally not considered within LCA. In other cases, the scores are only normalized (i.e. not weighted) and the decision of the severity of the impacts have to be taken by the decision-makers.

Health effects due to indoor exposure affect people in different ways depending on age, previous health conditions, exposure time and activities. The consideration of such factors within the LCA would imply a different approach or measurement methods. For example, if we want to measure the health impact on children or ill people, the worst-case scenario should be considered instead of the average scenario that is generally used within LCA.

In addition, some LCA methods aggregate the damage to human health over the whole lifetime of the building into a single score. This single score shows the relative impact of the building on the global population but it does not express the real damage that the building causes to individuals. In this way, the emissions of materials occurring in only a limited time period (e.g. after application of paint) would be distributed during the whole lifetime of the building and added to those materials that emit toxic substances during their whole lifetime. The consequences of this are that the calculated damage could be different from reality. For example, knowing that a building produces determined quantity of DALYs over its lifecycle can be useful for comparison, bit it does not express the damage produce to the lifetime of an individual in the building

### 4.2 Type of Exposure

In order to assess the health effects of a building on its occupants the analysis must consider the different types of exposed population related to building use and activities. The exposed population can be classified as:

1. Occupants of the building: it refers to the occupants of the house.
2. Construction workers during extraction, production, construction, maintenance, renovation and demolition activities.
3. Exposure of the population of the area could also be considered depending on the final purpose of the assessment. This exposure would refer to the damage produced by emissions of building materials and activities during the construction of the building.

The exposed population to be considered depends on the approach followed. For example, in life cycle assessment, the most common situation is to consider the population in a neighborhood, country or region, because the pollutants tend to flow to other areas. Population exposed to indoor damage should consist of the occupants of a dwelling or building. Even though the number of occupants of a dwelling can be known, the composition of the household in one dwelling cannot represent the household composition in all dwellings. For assessment, considered the average population in a region or country per household is a good method to determine the exposed population, nevertheless.

Composition of the population is an important factor for housing because some people are more exposed or sensitive to some toxic emissions than others, such as children, the elderly, and ill or disabled people. There are several factors that influence the increment of exposure of some people, which are mainly related with time of exposure and effects that some toxics have on people (Barendregt et al. 1996, Brauer et al. 2002, Murray and Lopez 1996, Murray 1999).

Children, the elderly and ill people tend to spend more time indoors, therefore the time of exposure is higher. In some countries or societies, women (and sometimes children) tend to spend long times near stoves and kitchens, increasing the exposure to combustion products; in these places, the difference of exposure between men and women or children is significant for some substances.

### 4.3 Positive and Negative Effects

The objective of a building, especially housing, is to protect people from dangers and from outdoor exposure. A building cannot only be considered to cause damage but also as a protection against dangerous agents, climate conditions and other hazards. In addition, noise and air pollution levels tend to be higher outdoors than indoors
with exception of some compounds such as Environmental Tobacco Smoke (ETS) and formaldehyde (Baechler et al. 1991).

Considering both negative health effects and beneficial effects of a house on human health is therefore more realistic. For example, even though some materials emit toxic substances to the indoor environment, they also have insulation properties that help to protect against external conditions; for an assessment, both characteristics must be taken into account in order to show a more accurate impact of the material (Figure 7).

Comparing positive effects of the building with negative effects of the building could be useful for decision-making. Weighting the damages (and benefits) separately is important because the areas of human health that such benefits and damages cover are not the same. For example, a given material may have good acoustic properties but produces toxic emissions; the benefits of the material application are related with annoyance while the negative effects of its use are related with carcinogens. Therefore, even if the number of DALYs produced by the material equals zero when positive and negative effects are aggregated, that does not mean that the damages disappear. Therefore, considerations about what is more important for human health and what is really necessary must be taken into account.

Figure 6. Positive and Negative effects of building characteristics and life style

5 Discussion and Conclusions

Human health has been considered in a number of databases and studies, often related with the environmental performance of a single product. Current LCAs for buildings consider human health through both midpoint and endpoint approaches. Nevertheless, most studies focus on damages to human health caused by building characteristics and not by behavior and lifestyle.

In the inventory of sources and stressors presented in section 3, the importance of behavior and lifestyle of the occupants of the building is shown by the multiple relations with building-related sources, and by the importance of behavior and lifestyle in the exposure to the stressors. A fifth column that links the stressors with effects to human health (e.g. carcinogens, respiratory diseases) was omitted from the inventory figure due to its complexity. Nevertheless, table 1 shows the health effects in relation to sources and stressors. The column would have shown how important all stressors in the indoor environment are to human health because of the contribution of the stressors to the health effects.

In this paper, three different approaches to human health related to housing have been defined depending on the scope of the study: the building physical characteristics approach, the use phase approach, and the life cycle approach. The approaches that could offer better bases for improving indoor conditions are related with physical improvement and maintenance of buildings. The approaches related to life cycle assessment are more useful for the aim of global policy. The approaches presented here represent both current research trends (building physical characteristics approach and life cycle approach) and a theoretical approach (use phase) that includes the missing factors (sources and stressors) in current methodologies. In practice, the use phase approach is difficult to follow because behavior, sources and effects on human health of some substances are still unknown.

One of the steps in the impact pathway analysis is to define the exposure to the stressors. Due to its importance within damage assessment, further research should be aimed at a better determination of the exposure of the buildings occupants. Time spent in different indoor environments (e.g. bathroom, kitchen, living room), and conditions of the occupants (e.g. elderly, children, disabilities) are important factors to consider within damage assessment and therefore should be taken into account.

More information about sources related with activities and lifestyle is also necessary in order to determine stressors during the use phase of the building that are not taken into account nowadays. These sources and their stressors have been already determined, but data about lifestyle and behavior of occupants is necessary for quantification.
References


Hoskins J.A. (2003), Health Effects Due To Indoor Air Pollution. Indoor And Built Environment 12, 427-433.


