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The Influence of Contaminants in Ambient Air on the Indoor Air Quality Part 1: Exposure of Children

Report of Work Package 1: Outline of the Study

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0 INTRODUCTION

It is the ambition of the Regional Government in Flanders, Belgium and in particular of the Environment and Health Unit (Ministry of Environment) to deploy a policy that includes all issues related to Environment and Health. This includes the development of a policy to reduce population exposure also in indoor environments.
In a previous study entitled "Development of a Flemish Policy for the Indoor Environment" (Goelen et al. 2003b), one of the identified future work items was to actually gather information about indoor pollution levels in Flanders, infiltration from outdoor to indoor environments and related population exposure in various micro-environments.

In this context, the main aim of this study is:
"to determine for sensitive groups of children the indoor environment exposure as a result of contaminants that occur in outdoor and indoor air".

Derived from this purpose, it is required to investigate:

- the indoor exposure for a first set of priority contaminants;
- the proportion of these contaminants infiltrating from outdoor to indoor.

Work package 1 of the project is summarised in this report. It is intended to determine the scope and outline of the study in consensus with the steering committee, after review of the report by a selection of international experts.

Besides the overall strategy to determine indoor exposure and indoor - outdoor pollution levels in relevant micro environments, this report will consider in particular the selection of:

- subgroups (0-18 years);
- indoor environments;
- outdoor/indoor pollutants and measurement methods/locations.

These considerations will answer the questions: who, where, what and how to measure.

Once the outline of the study (WP1) is determined, the 24 months project will continue with:

- the actual measurements and field work (WP 2);
- the interpretation of the results with recommendations for the government (WP3).

It is scheduled to finish WP1 by July-August 2005.
The external communication of the overall project is done by means of a (limited) website and a workshop. The proposed acronym for the project is "FLIES": Flanders Indoor Exposure Survey.

1 PRINCIPLE OF THE STRATEGY TO DETERMINE INDOOR EXPOSURE AND RELEVANT POLLUTION LEVELS

1.1 Objective 1: Generate Data on Indoor Exposure for a Set of Pollutants

The strategy to determine indoor exposure is principally based on actual measurements in indoor environments, at locations where individuals or subgroups spend a major part of their time. Individual and subgroup exposure is calculated by taking into account the measured concentration and the time spent in the corresponding micro environments. Surroundings that can be treated as homogeneous or well characterised in the concentrations of an agent (e.g. home, office, automobile, kitchen, store) are considered a micro environment. This term is generally used for estimating inhalation exposures.

The alternative strategy to perform real personal sampling on individuals is not retained mainly due to the nature of the selected groups (children).

The selected target group of children will be divided into subgroups with similar exposure patterns. The indoor environments considered are in general those defined in ISO 16000-1 (ISO 2004): dwellings, workrooms or workplaces in buildings not subject to health and safety inspections (e.g. offices, sales premises), public buildings (e.g. hospitals, schools, kindergartens, sports halls, libraries, restaurants, cinemas and other function rooms) and cabins of vehicles.

The data set will provide information, representative for the population in Flanders (Belgium), on:

- total exposure of individuals and subgroups;
- indoor exposure of individuals and subgroups, available as total indoor exposure, indoor exposure at homes and indoor exposure elsewhere.

1.2 Objective 2: Determine the Contribution of Outdoor Concentrations to Indoor Exposure

To determine in addition the effect of contaminants in outdoor air on the indoor air quality, the outdoor exposure and the infiltration of outdoor pollution needs to be quantified. Representative outdoor environments and locations are used. The indoor air measurements must be supplemented with a (as close as possible) simultaneous measurement of the outdoor air. When possible at the same level (floor) of the building. The outdoor air samples should be taken in the immediate vicinity of the building. Besides the pollutants of interest, the outdoor – indoor measurements must include an indicator pollutant which has theoretically only outdoor sources. The fraction of this contaminant measured indoors is then the result of the ventilation/infiltration characteristics of the indoor environment. The ventilation/infiltration constant (Goelen 2003a) allows to calculate contributions from outdoor pollution to the indoor environment. Details on the calculation are available in previous work (Goelen 2002).

The data obtained in this part of the study will provide information on:

- indoor concentration levels: average and were required for different rooms;
- the contribution of indoor and outdoor sources to the total indoor pollution level;
- the outdoor concentration in the vicinity of indoor environments (measurements complemented with data from monitoring networks).

It is obvious that, where required, the study is complemented with appropriate questionnaires to obtain information on indoor characteristics and daily activity patterns of volunteers so that an interpretation of the obtained data set is possible (WP3). The exposure analysis will result in:

- the average exposure of subgroups with differentiation for various parameters such as e.g. indoor characteristics, pollutant levels, personal activities;
- the fraction of indoor exposure due to outdoor pollution, taking into account different subgroups and indoor characteristics;
- the indoor exposure compared with outdoor exposure;
- the interpretation of exposure in relation to health effects for selected subgroups, taking into account various activity patterns.

These conclusions are compared with international and national ongoing studies. A preliminary search of such projects and studies is included in this report

It is in addition of utmost importance to formulate recommendations to regional and Belgian policy makers in this field. Recommendations may be expected in the field of:

- outdoor air :
  - are there pollutants that need special attention due to their infiltration into indoor environments;
  - should outdoor air guideline values take the infiltration and its effect on exposure into account;
  - are there special measures to be suggested/implemented;
- indoor air:
  - are there measures required to additionally prevent infiltration into e.g. dwellings;
  - is indoor exposure mainly due to indoor sources and what to do about it;
  - are there special measures to be suggested/implemented;
- population exposure:
  - what is the importance of exposure to air pollution as compared with other exposure routes;
  - are special measures required to prevent exposure to toxic pollutants;
  - any trends in exposure: will indoor exposure increase/decrease in the future.

The overall study is to be executed taking into account a number of preconditions which are:

- the obtained exposure and concentration data must be as representative as possible for the Flemish Region of Belgium;

- the selection of pollutants should be representative for outdoor (general outdoor sources e.g. traffic, heating, non specific industry) and indoor sources - pollutants that exclusively occur in indoor air are not selected;
- selected contaminants must be important from the health point of view;
- applied measurement methods should be appropriate for IAQ measurements, preference is given to instruments that are as manageable and simple as possible;
- suggested work load must be within the budget limits, limits available for each WP and especially the potential scope of WP2 (actual measurement campaign) is strongly influenced.

In the following paragraphs, a more detailed description is given of the selected subgroups, indoor environments and pollutants in order to further outline the study. Strong emphasis is put on the evaluation of existing scientific information.

2 SELECTION OF SUBGROUPS

Policy makers in Western countries recognise the importance for protecting children and providing them a maximally safe environment. WHO, the European Members States and the European Commission confirmed in CEHAPE (Children's Environment and Health Action Plan for Europe) their awareness for protecting children's health and environment as crucial to the sustainable development of countries.
Developing organisms, especially during early years of life, are often particularly susceptible, and may be more exposed than adults, to many environmental factors, such as polluted air and chemicals.

In this study, children are divided into 3 age groups based on comparable time-activity and sensitivity data:

- **0-6 years.** The major difference between infant/toddlers (0-3 y) and preschool aged children (3-6y) is the switch from day-care to kindergarten. Thus, considering equivalent type of exposure to toxic compounds, the two age groups can be combined;
- **6-12 years.** For this age group, home and school environments are still predominant. Although leisure activities such as sports and music academy are becoming more important;
- **12-18 years.** At this age leisure activities may be more important for exposure to toxic compounds, more specific exposure to environmental tobacco smoke in bars.

In order to study the contribution of indoor and outdoor environment in children's exposure to pollution, it is necessary to have information 1) on the activity pattern, time pattern and behaviour of children and 2) on the physiological characteristics of the study group.

2.1 Activity, Time Pattern and Behaviour

Several international studies have already studied activity patterns, time patterns and behaviour in young children (US-EPA 2001, OCHP 2003, Elgethun, K. et al. 2003, Adgate, J.L. et al. 2004, Kruize et al. 2000, Leech et al. 1997). This information will be extrapolated to children in Flanders.
Furthermore, data are available on time-activity patterns for Flanders for 12-18y old children (Glorieux I et al. 2001). However, no information on time spent indoor opposite outdoor is given.
Individual patterns can vary with respect to state of health, social status, residence (city centre, suburb, rural), etc.

In the following tables, percentages of time-activity patterns are shown for the selected age groups. The category “indoors other” includes the supermarket, shops, church, library, … "Bar/restaurant" was treated as a separate category because of the high likelihood of exposure to environmental tobacco smoke in such places.

Time Pattern in Various Micro-Environments, Glorieux et al. 2001	
Hours per day	*12-18y*
School / Indoors-other	5.8
in transport	1.3

Sampling: Respondents completed a diary during one weekday and one weekend day, determined beforehand by the researchers and distributed over the whole year (between Dec. '98 and Feb. '00).
Tool:24-hour diary. Respondents noted their main and subsidiary activities every 10 minutes in own words. After coding this resulted in 272 activity codes (according EUROSTAT guidelines), which were grouped in 11 major activities.

Time Pattern in Various Micro-Environments, Leech et al. 1997		
Hours per day	*0-11y(N=350)*	*12-17y (N=201)*
Indoors at home	17.2	16.3
School/ Indoors-other	4.0	4.7
Bar/restaurant	0.1	0.2
Outdoors	1.8	2.1
In vehicle	0.9	0.8

Sampling: performed in 2381 households (65% response rate), in four cities and their suburbs by random-digit dialling during three periods of the year (winter, spring and summer) in 1994-1995. Results of the three time periods were merged. Sampling at weekend and weekdays, with each day of the week of approximately equal frequency questioned.
Tool: 24-hour recall diary: respondents listed all the activities they could recall in 24-hour period. For each activity the location and number of minutes spent where questioned.

Time Pattern in Various Micro-Environments, Kruize et al. 2000				
Hours per day	*0-12y (*N= 1101)		*13-64y (N=2805)*	
	average	st dev	average	st dev
Indoors at home	17.2	4.01	14.9	4.26
School / Indoors-other	2.61	3.13	4.6	4.18
Outdoors	4.13	3.07	4.47	3.61
In vehicle	0.93	0.938	1.3	1.27

Sampling: calling of 10000 households (24% response rate), during three periods (winter, summer and summer with maxima above 25°C).
Tool: 24 hour-diary, with indication of location and activity every 15 minutes of the day (7 location codes and 20 activity codes).

Time Pattern in Various Micro-Environments, EPA 2001						
Hours per day	*1-2y (N=502)*		*3-5y (N=701)*		*6-10y (N=1033)*	
	average	st dev	average	st dev	average	st dev
Indoors at home	18.6	4.1	17.2	4.2	15.5	4.2
School / Indoors-other	5.5	3.5	5.3	2.8	6	1.5
Outdoors	3.9	3.4	4.1	3.2	4.1	4.2
In vehicle	1.2	1.1	1.3	1.5	1.2	1.4

Sampling: data based on three studies (California survey, Cincinnati (Ohio) diary study, National Activity Pattern Survey) including 2640 children of < 12 years old.
Tool: 24 hour-diary, with indication of location and activity data for every discrete major behaviour that is undertaken and disclosed.

Time-activity patterns show that children spend most their time indoors in their homes and in school. Therefore, primarily these locations are important to be included in the study for indoor/outdoor measurements. Detailed information on exposure of children indoor and outdoor is not available for Flanders.

The macro-activity pattern indoors at homes of children is summarised in the following table. Data for children aged 0-12 are adapted from US-EPA 2001. Patterns for the age category 12-18 y are based on Glorieux et al. 2001.

Macro-Activity Pattern in Home Micro-Environment				
	1-2y	*3-5y*	*6-12y*	*12-18y*
eat	1.4	1.1	1	1.4
sleep	11.8	10.9	9.8	9.6
bathe	0.5	0.5	0.4	0.8
play	3.2	2.4	1.9	0.9
tv/radio	2.0	2.5	2.9	2.2
read, write	0.6	0.8	1.1	0.5
relax	1.8	1.1	0.8	0.3

Children are a very predictable group when it comes down to their time activity pattern.
The young ones (age 0-3 year) spend their time predominantly in two places: at home and at a day-care centre for children. In Flanders a lot of children are looked after in small-scale day-cares or in a family day-care environment (either with direct family like grandparents, or in other residential buildings). At home, time is divided between sleeping room, living room or kitchen and bathroom (in order of time spent). Other activities like shopping and transportation do not take up much time. It may however be important to include car exposure.
A second homogenous group are the children aged 3 to 6. It might be worth considering extending this group to include 6-12 year olds, if leisure activities of this group do not dominate the overall time activity pattern. For both groups the home environment and the school environment are the two most important contributors to indoor exposure.
For 12-18 year olds, the impact of leisure activities might become increasingly important, as well as the exposure to environmental tobacco smoke.
Conclusion: to obtain the contribution of outdoor air pollution on indoor exposure the focus for measurements will be on residential buildings (home, day-care), and schools. To generate data about the indoor exposure, transport is worth considering. For older ages a set of data on exposure in other places (leisure activities) will be constructed as well.

The behaviour of children affects their exposure to pollutants; differences between age groups are reported in US-EPA 2001 and summarised in the following table.

Age Group	Behaviour
0-3 y	Mostly sleeping or sedentary from 0-3 months. Over 3 months: mouthing of hands and objects, breathing zone close to the floor, development of personal dust clouds, more vigorous activities From one year on: wider variety of breathing zones and engagement in more vigorous physical activities.
3-6 y	Moderate mouthing of hands and objects, continued increase of occupancy of outdoor spaces, more vigorous activities
6-11 y	Decreased oral contact with hands and objects, and dermal contact with surfaces. More time in school; sportive activities
12-16 y	Smoking might begin, passive smoking due to leisure activities. Workplace exposures might begin (student jobs, work-school combination). More time is being spent out of home.
16-18 y	Independent driving begins, expanded work opportunities.

2.2 Sensitivity

In the selection of the indoor environments and priority pollutants, the specific vulnerability of children has to be taken into account. Children's physiology and metabolism differs from adults, e.g. the children's respiratory minute volume per kg of body weight is roughly twice that of adults. Children aging 0-6y are a vulnerable age group for exposure to pollutants through breathing. For that reason, factors that determine children's particular vulnerability will be listed and considered in the study design and in the interpretation of the results. This information can be derived from the international literature (Ginsberg et al. 2005, US-EPA 2001 and US-EPA 2003):

Age Group	Physiological Characteristics
0-3 y	Breathing efficiency: ventilatory equivalent (VQ*) not available. Daily Inhalation Rate**: not available High oxygen requirement leading to higher inhalation rates un to three months of age Rapid growth and weight gain Deficiencies in hepatic enzyme activity up to 1 year, followed by a peak at the age of one year and stabilisation to adult levels Immature immune system up to 1 year. Body fat proportion increases, the increase begins to level off at six months
3-6 y	Breathing efficiency: VQ = 39 (3-5 y male and female) Daily Inhalation Rate: 14 m^3/day (3-5 y male and female) Stable weight gain and growth

Age Group	**Physiological Characteristics**
6-12 y	Breathing efficiency: VQ = 32 (for 6-10 y old male and female) Daily Inhalation Rate: 14 m^3/day (6-10y male) and 12 m^3/day (6-10 y female) Stable weight gain and growth up to 8-9 years old. Rapid skeletal growth and reproductive and endocrine changes starting at 8-9 years old.
12-18 y	Breathing efficiency: VQ = 27 (for 11-17 y old male and female, with VQ = 25 for males and VQ=28 for females). Daily Inhalation Rate: 14 m^3/day (11-15 y male), 13 m^3/day (11-15y female), 16 m^3/day (16-17 y male), and 12 m^3/day (16-17 y female). Rapid skeletal growth Rapid reproductive and endocrine changes

*VQ = unitless ratio of the minute volume to oxygen uptake (at body temperature, ambient pressure and water vapour saturated air). Variation coefficient on VQ estimates given is ca. 10 percent.
The Ventilatory Equivalent (VQ) is basically a measure of breathing efficiency, with lower values representing higher efficiencies. This means, the lungs require less ventilation per unit of oxygen consumed in generating the metabolic energy necessary for sustaining a given level op physical activity. As the respiratory system of a child matures, the ventilatory equivalent gradually decreases until it reaches a minimum value sometime in adolescence (US-EPA 2001).

** Daily Inhalation Rate = VE = $E \cdot H \cdot VQ \cdot F$
with:
E = energy expenditure or intake (kcal/day)
H = volume of oxygen at standard temperature and pressure, dry air consumed in the production of 1 kcal of energy expended, equals 0.21 L O_2/kcal
VQ = ventilatory equivalent
F = conversion factor, 0.001 m^3/L

The selection of participants in the study will be maximally synchronised with other ongoing environmental studies in children. This approach has the advantage that individual information already available (e.g. questionnaires, databases of external exposure in the past, etc.) can be used in the current study. Moreover, it reduces the practical work associated with recruitment. At the moment, a large biomonitoring project in newborns (n=1200) is running in Flanders. Within this project, a subgroup of 140 children was included in a follow-up study on asthma and allergy. These children live in an urban area (Antwerp) or in a rural area (East- and West-Flanders). They are currently participating in a 3-year follow-up study. The mothers are contacted on a regular basis and provide information on nutrition of child and living conditions of the family. There is a good willingness to co-operate in further studies. This group is the first set to be contacted to participate in this study. Another set of potential participants are 108, 1-year old children which are followed up in the ‘Op Pad’ study on the influence of functional nutrition on development of asthma/allergy. Furthermore, it possible that other households will be sampled in case there will not be not enough participants from the studies mentioned above. Besides the measurements in these dwellings, information on time activity patterns from 0-18 y old children living in will be gathered through diaries. Conclusively, based on time-activity pattern, behaviour and sensitivity data, children will (for data evaluation purposes) be divided in two age groups: 0-6 year old and 6-18 year old.

3 SELECTION OF INDOOR ENVIRONMENTS

The selection of indoor (micro-) environments is taken up in two steps:

- selection of places where children spend most of their time in general (see 2.1);
- selection of places based on and taking into account the characteristics of the building. Location of the building in order to be representative cannot be neglected. Other influences like smoking or specific hobbies must, where possible, be filtered out because this is not what we want to capture in this study.

3.1 Characterizing Buildings in Flanders

The objective is to characterise children's exposure indoor and the relative contribution of outdoor air pollution herein in Flanders. This requires representativeness of the measurement campaign based on a relevant choice of indoor environments. Therefore we need to choose a set of buildings and have to know which building characteristics are important, and how these parameters are distributed in Flanders. We will focus on residential buildings, day-care and schools, because of time spent there is the highest and these micro-environments will dominate the exposure.
For residential buildings we distinguish standalone houses, houses in a row, and apartment blocks. In Flanders some 1.9 million single-family houses exist, and newly built single family houses have decreased from about 25 000 per year in the beginning of the 90's to about 15 000 per year in 2002. Within the age group of 0 to 18 years, some 1.3 million children live in Flanders, of which the larger part (almost 80 %) in single family houses.

The exposure to pollutants indoors (residential) is function of the concentration outdoor and the penetration level or filtering level of the building, the sources indoor, the chemical adsorption indoors and the ventilation rate. To determine the fraction of the indoor exposure that relates to outdoor pollution the infiltration factor or indoor-outdoor relationship is needed. This unitless fraction takes into account the fraction that penetrates indoor and is available for exposure (taking into account deposition or adsorption). For the infiltration efficiency we assume the following relationship between concentrations indoor (C_{in}) and outdoor (C_{out}) (see also Wallace 1996, Allen et al. 2003 and Yeh et al. 2002), in the absence of indoor sources:

$$\frac{C_{in}}{C_{out}} = \frac{Pa}{a+k} \qquad (1)$$

The penetration factor P is the dimensionless fraction of the pollutant in ambient air that penetrates into the indoor environment. a is the air exchange rate, and k the deposition or adsorption rate. In his review Wallace (1996) concludes that the penetration factor is 1 for gases and close to one for PM_{10} and $PM_{2.5}$. This is confirmed by Allen et al. (2003) for $PM_{2.5}$. Ranges of deposition rates have been reported in Wallace (1996) and He et al. (2005) and compared with other studies. Allen et al. (2003) report additional results. The deposition rates for PM vary, not only between the different studies, but also as a function of PM size, from about 0.2 to 2.5 per hour, under different air exchange rates. Adsorption data for gases is summarised in earlier work. For the study it is thus necessary to obtain air exchange rates and derive the infiltration efficiency. It is also required to have a reasonable idea of the distribution of air exchange rates, or (even better) of infiltration efficiencies for pollutants in the residential sector in Flanders. Different sources are to be used here:

1. The international literature on infiltration in residential buildings is quite extensive. It needs to be checked and compared with own measurements. If measurements of infiltration or air exchange rates are within literature boundaries it is probably safe to assume that infiltration efficiencies in general in Flanders do not differ from those in literature.
2. National studies give insight in the existing volumes (m^3) and ventilation rates (m^3/h) in residences in Flanders, from which a distribution of air exchange rates can be derived[1].

Air tightness is measured as the airflow under standard pressure (in Belgium 50 Pa). A measure of the air tightness or permeability of a building is n50, the air flow through a controlled opening (e.g. blower door) under 50 Pa, normalised to the volume of the building. The air tightness n50 is assumed to correlate with the season-averaged air exchange rate (defined as n, without the influence of manual ventilation habits):

$$n = \frac{n_{50}}{f} \tag{2}$$

with f a factor describing exposure to wind and varying from 10 (for highly exposed single buildings) to 30 (for shielded or from wind protected buildings). A factor of 20 is used in SenViVV[2] 1998. This is in line with European data for the estimation of natural ventilation and infiltration (CEN/TC 89 N 476 E 1995, see also annex f for additional data). In Flanders n50 varies from 1.8 to 25 h^{-1}, with an average of 7.8 h^{-1}. And hence the air exchange rate varies from 0.1 to 6 h^{-1}, with an average value of 0.4 h^{-1}. Apartments have the lowest air exchange rate (about 0.2 h^{-1}); houses in a row have an exchange rate of about 0.25 h^{-1}. Houses with one common wall or single houses have the highest air exchange rates (0.4 to 0.5 h^{-1}). If all residences that were studied adhered to ventilation standards (Belgian standard NBN D50-001), the air exchange rate would vary between 0.3 and 0.95 h^{-1}, with an average of 0.6 h^{-1}. The SenViVV study aimed at representativeness for the residential sector in Flanders. It is concluded that the 200 residences selected for this study were representative for the new built residences between 1987-1993. Because of the inclusion of residences built in the period before 31/8/1992, without isolation and ventilation requirements, it is plausible to use the data for about 30 % of the residences in Flanders, built after the oil crisis in 1973, the authors suggest.

These considerations however do not include the influence of inhabitants on ventilation. It is generally agreed that activities like window opening, opening of doors etc… can increase air exchange rates with a factor 2 to 5 (Wallace 1996, He et al. 2005). There is

[1] Some definitions to assure accurate translation of Dutch terminology:
Air exchange rate = ventilatievoud,
Air tightness = luchtdichtheid

[2] SenViVV: Study ordered by the Flemish Government in the VLIET framework. The energy dimensions of newly built houses (e.g. ventilation, isolation, heating) were investigated.

to our knowledge very limited information or data in literature to disentangle natural ventilation due to building characteristics from ventilation through inhabitant activities. We will inquire into this further during the study. As a first lead there is the study of He et al. (2005) where deposition rates for particles where investigated under minimal (i.e. without opening windows and doors) and normal ventilation conditions. Air exchange rates for 14 houses have been measured but not reported individually. The Air Infiltration and Ventilation Centre of the IEA gives additional clues and criteria to account for window opening and occupancy (AIVC TN 57 2002 and TN 23 1988).

3.2 Location and Source Specific Inclusion Criteria.

We are interested in the contribution of ambient or general concentrations of outdoor air pollution to the exposure indoors. Therefore we avoid the presence of specific large industrial sources in the vicinity of the selected homes, by controlling this in the selection of residences. This limitation in the choice of residences is achieved by a simple visual comparison of residence location, nearest industrial sites and prevalent wind direction on a map. We think this will put a lower bound to the exposure of outdoor pollution indoors. In the vicinity of large sources the contribution of some specific ambient pollutants to the exposure indoors will be higher.
This does not limit conclusions or recommendations with respect to the general question of exposure of children indoor due to pollutants that also have an outdoor component. Near to specific sources these conclusions and recommendations will hold a fortiori.

One aspect of the study is to select pollutants that are interesting from the perspective of both indoor and outdoor presence and sources. In literature the exposure to ETS (Environmental tobacco smoke) is a dominating factor in exposure indoors where people smoke. It is well known that ETS affects children's health (e.g. Matt et al., 2004), and it is therefore not the focus of this study. We control for this by selecting smoke free families and residences. The same argument applies for open (wood) fires. This is also a specific source of indoor pollution, that is well known, and that we want to avoid here.

Important features like dwelling age, the insulation level and building characteristics, recent refurbishing and information on the presence of specific materials are collected through questionnaires. Habits like manual ventilation (opening windows etc...) are also to be noted in questionnaires (see later WP2 about the questionnaires). The SenViVV study also tested and validated a questionnaire to estimate the airtightness (n_{50}), that we can use here as a good proxy for measurements.

For school buildings some distinction has to be made also: we propose to try to include older and newer schools. Proximity to roads is a further attribute to be considered in the analysis. Proximity to traffic is an indicator in several epidemiological studies for effects on health in the general population (Hoek et al. 2002) and on children (Schwartz 2004, Spengler 2004 and Janssen 2003). It is important to have an understanding of the variation in exposure due to traffic proximity.

4 ESTIMATING EXPOSURE

Supported by measurements for selected pollutants the indoor exposure is estimated. Exposure is defined as the sum of the products of the concentration in a micro-environment with the time spent in this micro-environment. This exposure can then be averaged out:

Indoor exposure E_i = $\sum_{micro-environment\ i}(T_i \times C_i)$

Average indoor exposure $E_{i,av}$= $\frac{\sum_{micro-environment\ i}(T_i \times C_i)}{\sum_{micro-environment\ i}(T_i)}$

with:

T_i: time spent in micro-environment i,

C_i: concentration in micro-environment i.

We want to determine indoor exposure everywhere and relate the exposure at home or at school or day-care with outdoor air. Assume that the exposure indoor is a sum of contributions:

$E_{indoor}= C_{indoor,\ home} \text{ x } T_{indoor,\ home} + C_{indoor,\ other} \text{ x } T_{indoor,\ other} + C_{transport} \text{ x } T_{transport}$ (1)

with 'indoor, other' indicating school or day-care. The relation with outdoor concentrations can be made through

$E_{indoor}= F_{home} \text{ x } C_{outdoor,\ home} \text{ x } T_{indoor,\ home} + F_{other} \text{ x } C_{outdoor,\ other} \text{ x } T_{indoor,\ other} + C_{transport} \text{ x } T_{transport} + C_{indoor\ sources} \text{ x } T_{indoor}$ (2)

Here we obtain a simple description of the contribution of outdoor concentrations of pollutants to indoor exposure per micro-environment, through the infiltration efficiency F per micro-environment. The infiltration efficiency is calculated using the information outlined in 3.1, and is validated in some of the measurements were time dependant concentrations are measured. The contribution from indoor sources is grouped and time-weighted in the last term of equation, but is unknown, since we do not try to measure this contribution directly (2):

$C_{indoor\ sources} \text{ x } T_{indoor} = C_{indoor\ sources,\ home} \text{ x } T_{indoor\ sources,\ home} + C_{indoor\ sources,\ other} \text{ x } T_{indoor\ sources,\ other}$ (3)

We could also derive the overall or average contribution of outdoor pollution to indoor exposure when using the relation

$E_{indoor}= F \text{ x } C_a \text{ x } T_{indoor} + C_{indoor\ sources} \text{ x } T_{indoor}$ (4)

The ambient concentration being measured at monitoring stations nearby, and T_{indoor} being the sum over all times spent indoor.

Measuring the different factors $C_{indoor,\ home}$, $C_{indoor,\ other}$, $C_{transport}$ (1) and the outdoor concentrations near these different micro-environments will provide E_{indoor}, and calculating the F_{home} and F_{other} will give the overall indoor source contribution, $C_{indoor\ sources}$ from (2), without exactly knowing the different sources. Questionnaire information will provide extra knowledge on these sources. Together with C_a and (4) we can establish the average relation F between C_a and E_{indoor}.

5 SELECTION OF POLLUTANTS AND MEASUREMENT METHODS

The selection of the pollutants can be based on several international references, as well as on own experience concerning the measurement of dangerous substances in air, to which children are exposed. Based on the background information found, a selection of compounds to be measured is made. Apart from the scientific view, also cost-effectiveness and the practical circumstances of the actual measurement methods will have to be taken into consideration to aim at an optimum output of results.

5.1 Pollutants Studied in Other Projects

The tables in this paragraph give an overview of the pollutants regulated by (inter)national instances, measured in other studies or of which data are published in articles. This is not a limitative list; selections were made from the available references to cover a wide range of situations, as it is expected to be found in the measurement locations of interest.

Several sources have been consulted to complete these tables. For a selection of large international projects, more information about the projects can be found in chapter 7. The other references can be found in the bibliography (chapter 8). It is obvious that the ambition is not to include all existing work, but a representative selection.

Table 1: Overview of the Pollutants Included in Legislation/Standards

Pollutant	Legislation and Standards			
	ISO:16000-1 (International)	**Flemish Indoor Environment Resolution (Belgium) BS D. 2004-4160)**	**Exposure Guidelines for Residential indoor Air Quality (Canada)**	**BR-450: A Protocol for the assessment of indoor air quality inn homes and office buildings (UK)**
PARTICLES				
Diesel soot	-	-	-	-
Black Smoke	-	-	-	-
Suspended particles	x	-	-	-
PM10	-	x	x	-
PM2.5	-	x	x	-
COMBUSTION/INORGANIC GASES				
NO	-	-	-	-
NO_2	x	x	x	x
NO_x	-	-	-	-
CO	x	x	x	x
CO_2	x	x	x	-
O_3	x	x	x	x
SO_2	x	-	x	x
PAH	x	-	-	-

Pollutant	**Legislation and Standards**			
	ISO:16000-1 (International)	**Flemish Indoor Environment Resolution (Belgium) BS D. 2004-4160)**	**Exposure Guidelines for Residential indoor Air Quality (Canada)**	**BR-450: A Protocol for the assesment of indoor air quality imn homes and office buildings (UK)**
(S)VOC				
C10-C20 alkanes/alkenes/aromatics	x	-	-	-
TVOC (Total Volatile Organic Compounds)	-	x	-	x
Benzene	x	x	-	x
Toluene	x	x	-	x
Ethylbenzene	-	-	-	x
Xylenes	-	-	-	x
1,2,4-Trimethylbenzene	-	-	-	-
Styrene	x	-	-	x
p-dichlorobenzene	x	-	-	x
1,1,1-Trichloroethane	x	-	-	-
Trichloroethene	x	x	-	-
Tetrachloroethene	x	x	-	x
Vinyl chloride	-	-	-	x
pentane / cyclohexane / ethanol	x	-	-	-
glycol ether, e.g. 2-butoxyethanol	x	-	-	-
Butyl acetate	-	-	-	-
MTBE	-	-	-	-
Formaldehyde	x	x	x	x
Acetaldehyde	x	x	x	x
Acrolein	x	-	x	x
Methylene diisocyanate	-	-	-	-
PESTICIDES/BIOCIDES			-	-
Triclosan	-	-	-	-
Permethrin	-	-	-	-
TERPENES			-	-
alfa-Pinene	x	-	-	-
d-Limonene	x	-	-	-
FLAME RETARDANTS				
Hexabromocyclododecane	-	-	-	-
Polybromodiphenylethers	-	-	-	-
PHYSICAL				
Radon	x	-	x	x
BIOLOGICAL	-	-	-	-
microbial contaminants	-	x	-	-

Pollutant	Legislation and Standards			
	ISO:16000-1 (International)	Flemish Indoor Environment Resolution (Belgium) BS D. 2004-4160)	Exposure Guidelines for Residential indoor Air Quality (Canada)	BR-450: A Protocol for the assesment of indoor air quality inn homes and office buildings (UK)
OTHERS	see 1	see 2	-	-

1	4-phenolcyclohexene, trimeric isbutene, dichloromethane, HCH-isomeren, pentachlorophenol, PCB's, Polyhalogenated dibenzo p-dioxines.furans, ketones, 1-ethylalcohol, phenols, esters, phtalates, Nicotine, Ammonia, Mercury, Lead, Settled Dusts, Asbestos, Fibrous dusts, aerosols
2	Fibres

Table 2: Overview of the Pollutants Studied in a Selection of International Studies

Pollutant	International Studies																						
	AIRALLERG	AIR4EU	AIRNET	APHEA	APHEIS	APMoSPHERE	CSRB : Observatoire de la qualité de l'intérieur	EXPAH	EXPOLIS	FIRE	GEreS	HEAPSS	HEARTS	HELIOS	INDEX	MACBETH	PCBRISK	PEOPLE	PINCHE	TEAM	TRAPCA	ULTRA	WHO: Air Quality Guidelines for Europe
PARTICLES																							
Diesel soot	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Smoke	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Suspended particles	-	-	-	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PM10	-	x	x	-	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	x	x	-
PM2.5	x	x	x	-	x	x	-	-	x	-	-	x	x	-	-	-	-	-	-	-	-	x	-
COMBUSTION/ INORGANIC GASES																							
NO	x	-	-	-	-	-		-	-	-	-	-	-	x	-	-	-	-	-	-	x	-	-
NO_2	x	x	-	-	x	x	x	-	x	-	-	-	x	x	x	-	-	-	-	-	x	-	-
NO_x	-	-	-	x	-	x	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-
CO	-	x	-	-	x	x	x	-	x	-	-	-	x	-	x	-	-	-	-	-	x	-	-
CO_2	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O_3	-	x	-	x	x	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-
SO_2	-	x	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
PAH	-	-	-	-	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Pollutant	**International Studies**																						
	AIRALLERG	**AIR4EU**	**AIRNET**	**APHEA**	**APHEIS**	**APMoSPHERE**	**CSRB : Observatoire de la qualité de l'intérieur**	**EXPAH**	**EXPOLIS**	**FIRE**	**GEreS**	**HEAPSS**	**HEARTS**	**HELIOS**	**INDEX**	**MACBETH**	**PCBRISK**	**PEOPLE**	**PINCHE**	**TEAM**	**TRAPCA**	**ULTRA**	**WHO: Air Quality Guidelines for Europe**
(S)VOC																							
C10-C20 alkanes / alkenes / aromatics	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TVOC (Total Volatile Organic Compounds)	-	-	-	-	-	-	-	-	-	-		-	-	-		-	-	-	-		-	-	-
Benzene	-	x	-	-	-	-	x	-	x	-	x	-	x	-	x	x	-	x	-	-	-	-	-
Toluene	-	-	-	-	-	-	x	-	x	-	x	-	-	-	x	-	-	-	-	-	-	-	-
Ethylbenzene	-	-	-	-	-	-	x	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Xylenes	-	-	-	-	-	-	x	-	x	-	x	-	-	-	x	-	-	-	-	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Styrene	-	-	-	-	-	-	x	-	x	-	x	-	-	-	x	-	-	-	-	-	-	-	-
p-dichlorobenzene	-	-	-	-	-	-	x	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-	-	-	x	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	-	-	-	-	-	-	x	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Tetrachloroethene	-	-	-	-	-	-		-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Vinyl chloride	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pentane / cyclohexane / ethanol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
glycol ether, e.g. 2-butoxyethanol	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Butyl acetate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Pollutant	**International Studies**																						
	AIRALLERG	**AIR4EU**	**AIRNET**	**APHEA**	**APHEIS**	**APMoSPHERE**	**CSRB : Observatoire de la qualité de l'intérieur**	**EXPAH**	**EXPOLIS**	**FIRE**	**GEreS**	**HEAPSS**	**HEARTS**	**HELIOS**	**INDEX**	**MACBETH**	**PCBRISK**	**PEOPLE**	**PINCHE**	**TEAM**	**TRAPCA**	**ULTRA**	**WHO: Air Quality Guidelines for Europe**
MTBE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Formaldehyde	-	-	-	-	-	-	x	-	-	-	x	-	-	-	x	-	-	-	-	-	-	-	-
Acetaldehyde	-	-	-	-	-	-	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-
Acrolein	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methylene diisocyanate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PESTICIDES /BIOCIDES							x																
Triclosan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Permethrin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
TERPENES							x																
alfa-Pinene	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-
d-Limonene	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-
FLAME RETARDANTS																							
Hexabromocyclododecane	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
Polybromodiphenylethers	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
PHYSICAL																							
Radon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
BIOLOGICAL							-																
microbial contaminants	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-

Pollutant	**International Studies**																						
	AIRALLERG	**AIR4EU**	**AIRNET**	**APHEA**	**APHEIS**	**APMoSPHERE**	**CSRB : Observatoire de la qualité de l'intérieur**	**EXPAH**	**EXPOLIS**	**FIRE**	**GEreS**	**HEAPSS**	**HEARTS**	**HELIOS**	**INDEX**	**MACBETH**	**PCBRISK**	**PEOPLE**	**PINCHE**	**TEAM**	**TRAPCA**	**ULTRA**	**WHO: Air Quality Guidelines for Europe**
OTHERS	-	-	-	-	-	-	-	-	see 3	-	see 4	-	-	-	see 5	-	see 6	-	see 7		see 8	-	
3	hexane, nonane, decane, cyclohexane, undecane, hexanal, benzaldehyde, octanal, naphthalene, propylbenzene, trimethylbenzenes, 2-methyl-1-propanol, 1-butanol, 2-ethyl-1-hexanol, phenol, 1-octanol, 1,1,2-trichloroethane, 1-methyl-2-pyrrolidinone, 3-caren																						
4	n-hexane, n-heptane, n-octane, n-nonane, n-decane, n-undecane, n-dodecane, n-tridecane, isohexanes, isoheptanes, isooctanes, isononanes, methylcyclopentane, cyclohexane, methylcyclohexane, beta-Pinene, alpha-terpinene, ethylacetate, isobutylacetate, methyl ethyl ketone, 4-methyl-2-pentanone, hexanal, n-butanol. isobutanol, isoamylalcohol, 2-ethylhexanol, iso- and n-propylbenzene,2-ethyltoluene, 3- + 4-ethyltoluene, 1,2,3-trimethylbenzene, 1,3,5-trimethylbenzene, naphthalene,																						
5	ammonia, Naphthalene. (Only Phase 3 and Priority are included, other compounds are considered in the project)																						
6	OH-PCBs, MeSO2–PCBs, PCDDs, PCDFs, coplanar PCBs, heavy metals (Cd, Hg, Pb, Mn, Zn, Se), bioassays of dioxin-like activity and xenoestrogenic activity																						
7	http://www.pinche.hvdgm.nl/resource/pdf/documents/interim/pinche_exposure_interim_report.pdf ; pg. 9																						
8	airborne particulate																						

Table 3:Overview of the Pollutants Withdrawn in National Studies

Pollutant	**National Studies**								
	Réflexion d'Eupen	**GOELEN: Development Flemish Policy**	**Pilot project 'Environment and Health' (Milieu en Gezondheid)**	**Biomonitoring 'Flemish Environment and Health Study (FLEHS)'**	**Neurological follow-up study**	**Immunological follow-up study**	**Comparison and correlation of biomonitoring and environmental monitoring networks**	**Kuske: Les Pollutions dans l'air à l'interieur des bâtiments**	**COMEAP: Guidance on the Effect on Health of Indoor Air Pollutants**
PARTICLES									
Diesel soot	-	-	-	-	-	-	-	-	-
Black Smoke	-	-	-	-	-	-	-	-	-
Suspended particles	-	x	-	-	-	-	-	-	x
PM10	-	-	-	-	-	-	-	-	-
PM2.5	-	-	-	-	-	-	-	-	-
COMBUSTION/INORGANIC GASES									
NO	-		-	-	-	-	-	x	x
NO_2	-	x	-	-	-	-	-	x	x
NO_x	-	-	-	-	-	-	-	-	-
CO	-	x	-	-	-	-	-	x	x
CO_2	-	x	-	-	-	-	-	-	-
O_3	-	x	-	-	-	-	-	-	-
SO_2	-	x	-	-	-	-	-	-	-
PAH	-	x	-	-	-	-	-	-	x

Pollutant	National Studies								
	Réflexion d'Eupen	**GOELEN: Development Flemish Policy**	**Pilot project 'Environment and Health' (Milieu en Gezondheid)**	**Biomonitoring 'Flemish Environment and Health Study (FLEHS)'**	**Neurological follow-up study**	**Immunological follow-up study**	**Comparison and correlation of biomonitoring and environmental monitoring networks**	**Kuske: Les Pollutions dans l'air à l'interieur des bâtiments**	**COMEAP: Guidance on the Effect on Health of Indoor Air Pollutants**
(S)VOC									
C10-C20 alkanes/alkenes/aromatics	-	-	-	-	-	-	-	-	-
TVOC (Total Volatile Organic Compounds)	-	-	-	-	-	-	-	-	-
Benzene	x	x	x	-	-	x	x	x	x
Toluene	x	x	-	-	-	-	-	x	-
Ethylbenzene	-	x	-	-	-	-	-	-	-
Xylenes	-	x	-	-	-	-	-	x	-
1,2,4-Trimethylbenzene	x	-	-	-	-	-	-	-	-
Styrene	-	x	-	-	-	-	-	-	-
p-dichlorobenzene	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-	-	-	-	x	-
Trichloroethene	x	-	-	-	-	-	-	x	-
Tetrachloroethene	-	x	-	-	-	-	-	x	-
Vinyl chloride	x	-	-	-	-	-	-	-	-
pentane / cyclohexane / ethanol	-	-	-	-	-	-	-	-	-
glycol ether, e.g. 2-butoxyethanol	x	-	-	-	-	-	-	-	-

Pollutant	National Studies								
	Réflexion d'Eupen	**GOELEN: Development Flemish Policy**	**Pilot project 'Environment and Health' (Milieu en Gezondheid)**	**Biomonitoring 'Flemish Environment and Health Study (FLEHS)'**	**Neurological follow-up study**	**Immunological follow-up study**	**Comparison and correlation of biomonitoring and environmental monitoring networks**	**Kuske: Les Pollutions dans l'air à l'interieur des bâtiments**	**COMEAP: Guidance on the Effect on Health of Indoor Air Pollutants**
Butyl acetate	-	-	-	-	-	-	-	-	-
MTBE	-	-	-	-	-	-	-	-	-
Formaldehyde	x	x	-	-	-	-	-	x	x
Acetaldehyde	x	x	-	-	-	-	-	-	-
Acrolein	-	x	-	-	-	-	-	-	-
Methylene diisocyanate	x	-	-	-	-	-	-	-	-
PESTICIDES/BIOCIDES		x	-	-	-	-	-	x	
Triclosan	x	-	-	-	-	-	-	-	-
Permethrin	x	-	-	-	-	-	-	x	-
TERPENES			-	-	-	-	-		
alfa-Pinene	x	-	-	-	-	-	-	-	-
d-Limonene	x	-	-	-	-	-	-	-	-
FLAME RETARDANTS									
Hexabromocyclododecane	x	-	-	-	-	-	-	-	-
Polybromodiphenylethers	x	-	-	-	-	-	-	-	-
PHYSICAL									
Radon	-	x	-	-	-	-	-	x	-
BIOLOGICAL	-	x	-	-	-	-	-	x	-
microbial contaminants	-	-	-	-	-	-	-		-

Pollutant	National Studies								
	Réflexion d'Eupen	GOELEN: Development Flemish Policy	Pilot project 'Environment and Health' (Milieu en Gezondheid)	Biomonitoring 'Flemish Environment and Health Study (FLEHS)'	Neurological follow-up study	Immunological follow-up study	Comparison and correlation of biomonitoring and environmental monitoring networks	Kuske: Les Pollutions dans l'air à l'interieur des bâtiments	COMEAP: Guidance on the Effect on Health of Indoor Air Pollutants
OTHERS	-	see 6	Biomarkers of exposure and effect	Biomarkers of exposure and effect	Biomarkers of exposure and neurological effect	Biomarkers of exposure and immunological effect	outdoor; Cd, Pb, B(a)P, VOC's	see 7	see 8
6	Lead, Asbestos								
7	Lead, Asbestos								
8	Benzo-a-Pyrene								

Table 4: Overview of the Pollutants Monitored in a Selection of International (recent) Literature

Pollutant	**Selection of International Literature**													
	Sexton et Al. 2004	**Wilford et al. 2004**	**Srivastava et al. 2003**	**Gauvin et al. 2002**	**Fromme et al. 2004**	**Goyer 1990**	**Blondeau et al. 2005**	**Brauer et al. 2002**	**El Fadel et al. 2003**	**Lau et al. 2002**	**Zhu et al. 2004**	**Batterman et al. 1995**	**He et al. 2005**	**Wensing et al. 2005**
PARTICLES						x								
Diesel soot	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Black Smoke	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Suspended particles	-	-	x	-	-	-	-	-	x	-	-	-	-	-
PM10	-	-	-	-	-	-	x	-	-	-	-	-	-	-
PM2.5	-	-	-	x	-	-	-	x	-	-	-	-	-	-
COMBUSTION/INORGANIC GASES														
NO	-	-	-	-	-	-	x	-	-	-	-	-	-	-
NO_2	-	-	-	-	-	-	x	x	-	-	-	-	-	-
NO_x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO	-	-	-	-	-	x	-	-	x	-	-	-	x	-
CO_2	-	-	-	-	-	x	-	-	-	-	-	x	-	-
O_3	-	-	-	-	-	x	x	-	-	-	-	-	-	-
SO_2	-	-	-	-	-	-	-	-	-	-	-	-	x	-
PAH	-	-	-	-	x	-	-	-	-	-	-	-	-	-

Pollutant	Selection of International Literature													
	Sexton et Al. 2004	Wilford et al. 2004	Srivastava et al. 2003	Gauvin et al. 2002	Fromme et al. 2004	Goyer 1990	Blondeau et al. 2005	Brauer et al. 2002	El Fadel et al. 2003	Lau et al. 2002	Zhu et al. 2004	Batterman et al. 1995	He et al. 2005	Wensing et al. 2005
(S)VOC														
C10-C20 alkanes/alkenes/aromatics	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TVOC (Total Volatile Organic Compounds)	-	-	-	-	-	x	-	-	-	-	-	x	-	-
Benzene	x	-	-	-	-	-	-	-	-	x	-	-	-	-
Toluene	x	-	-	-	-	-	-	-	-	x	-	-	-	-
Ethylbenzene	x	-	-	-	-	-	-	-	-	x	-	-	-	-
Xylenes	x	-	-	-	-	-	-	-	-	x	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Styrene	x	-	-	-	-	-	-	-	-	-	-	-	-	-
p-dichlorobenzene	x	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	x	-	-	-	-	-	-	-	-	-	-	-	-	-
Tetrachloroethene	x	-	-	-	-	-	-	-	-	-	-	-	-	-
Vinyl chloride	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pentane / cyclohexane / ethanol	-	-	-	-	-	-	-	-	-	-	-	-	-	-
glycol ether, e.g. 2-butoxyethanol	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Butyl acetate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MTBE	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Pollutant	Selection of International Literature													
	Sexton et Al. 2004	**Wilford et al. 2004**	**Srivastava et al. 2003**	**Gauvin et al. 2002**	**Fromme et al. 2004**	**Goyer 1990**	**Blondeau et al. 2005**	**Brauer et al. 2002**	**El Fadel et al. 2003**	**Lau et al. 2002**	**Zhu et al. 2004**	**Batterman et al. 1995**	**He et al. 2005**	**Wensing et al. 2005**
Formaldehyde	-	-	-	-	-	x	-	-	-	-	-	-	-	-
Acetaldehyde	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acrolein	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methylene diisocyanate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PESTICIDES/BIOCIDES	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Triclosan	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Permethrin	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TERPENES	-	-	-	-	-	-	-	-	-	-	-	-	-	-
alfa-Pinene	x	-	-	-	-	-	-	-	-	-	-	-	-	-
d-Limonene	x	-	-	-	-	-	-	-	-	-	-	-	-	-
FLAME RETARDANTS		x												
Hexabromocyclododecane	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polybromodiphenylethers	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PHYSICAL														
Radon	-	-	-	-	-	x	-	-	-	-	-	-	-	-
BIOLOGICAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
microbial contaminants	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Pollutant	Selection of International Literature													
	Sexton et Al. 2004	Wilford et al. 2004	Srivastava et al. 2003	Gauvin et al. 2002	Fromme et al. 2004	Goyer 1990	Blondeau et al. 2005	Brauer et al. 2002	El Fadel et al. 2003	Lau et al. 2002	Zhu et al. 2004	Batterman et al. 1995	He et al. 2005	Wensing et al. 2005
OTHERS	CCl4, chloroform, dichloromethane	-	-	-	-	Nicotine	-	-	-	-	UFP's	-	RPM's, arsenic, fluoride	Plastic additives (flame retardants & plasticisers

5.2 Pollutants: Properties and Measurement Methods

Another criterion for the choice of the pollutants to be sampled are the health effects associated with them. Therefore, the pollutants included in the previous paragraph, are listed with their respective effects on human health, as far as found in literature. Documents from the WHO were the primary source for this paragraph, where necessary completed with information found in the studies and articles from paragraph 5.1. If needed additional information was retrieved (Chao 2001, Kindzierski 2001, GGD 1996 and Proctor 1991)
Since this study is concentrated on the indoor – outdoor relation of the pollutants, the different sources are listed in the tables. Pollutants that have only (known) indoor sources will not be included in this study. The expected concentration range is included because it affects the measurement methods to be applied.

Table 5: Pollutants: Health Effects

Pollutant	Health Effects		IARC
	Acute	**Chronically**	
PARTICLES	Respiratory and Cardiovascular Disorders	Cardiopulmonar Disorders/Bronchopulmonar Cancer	-
Diesel soot			
Black Smoke			
Suspended particles			
PM10			
PM2.5			
COMBUSTION/INORGANIC GASES			
NO	No information	Can induce changes in long and airways	-
NO_2	Lung function	20 % increase in risk of childhood respiratory illness corresponding to an increase of 30 µg/m³ NO2 level	-
NO_x	Neurotoxical- Cardiovascular disorders	Cardiovascular Disorders	-
CO	Inhibition of Cellular Respiration	No information	-
CO_2	Central Nervous System	No information	-
O_3	Respiratory Disorders	Changes in lung and air way have been reported	-
SO_2	Respiratory Disorders	No experimental evidence	-
PAH	Possible role in inflammations	Carcinogenic	-
(S)VOC			
C10-C20 alkanes/alkenes/aromatics	-	-	-
TVOC (Total Volatile Organic Compounds)	no specific effects, might be used as an indicator		
Benzene	Neurotoxic/Immunotoxic	Leukaemia	Carcinogenic Class 1

Pollutant	Health Effects		IARC
	Acute	**Chronically**	
Toluene	Neurotoxic	Neurotoxic	Carcinogenic Class 3
Ethylbenzene	-	Under Development	-
Xylenes	Neurotoxic	Neurotoxic	Carcinogenic Class 3
1,2,4-Trimethylbenzene	Irritating, headache,	Neurotoxic , Asthmatically Bronchitis, Anaemia	-
Styrene	Neurotoxic	Neurotoxic/lung cancer	Carcinogenic Class 2B
p-dichlorobenzene	Respiratory Disorders	Kidney Disorders	-
1,1,1-Trichloroethane	Neurotoxic	No effects Found	-
Trichloroethene	Neurotoxic	Disorders of Liver/Kidney/Endocrine Systems and Immunity/Testicle- Lymph- and Oesophageal Cancer	Carcinogenic Class 2A
Tetrachloroethene	Kidney Disorders	Neurotoxic/Cancer	Carcinogenic Class 2A
Vinyl chloride	Disorders of the central nervous system	"vinyl chloride disease"	Carcinogenic Class 1
pentane / cyclohexane / ethanol	Cyclohexane and Ethanol are Irritating, no date available on pentane	No information	-
glycol ether, e.g. 2-butoxyethanol	Irritating (Eyes, Respiration)	No information	-
Butyl acetate	Neurotoxic/Irritating/Respiratory Disorders	No information	-
MTBE	Neurotoxic/Irritating/Respiratory Disorders	Liver Disorder	-
Formaldehyde	Respiratory Disorders	Nasal- and Pharynx Cancer	Carcinogenic Class 1
Acetaldehyde	Respiratory Disorders	Nasal- and Larynx Cancer	Carcinogenic Class 2B
Acrolein	Neurotoxic/Irritating	No Effects Found	Carcinogenic Class 3
Methylene diisocyanate	Respiratory Disorders	Respiratory Disorders	Carcinogenic Class 3

Pollutant	Health Effects		IARC
	Acute	**Chronically**	
PESTICIDES/BIOCIDES			
Triclosan	Irritating/Neurological Disorders	Asthma, Resin- and Movement Disorders, immunosuppressant, polyneuropathy	Carcinogenic Class 3
Permethrin	not evaluated, but has the same structure and formula as e.g. dioxins	Behaves as a super-antibiotic (can create super bacteria's)	-
TERPENES			
alfa-Pinene	Headache/confusion	Lung- and Kidney Disorders	-
d-Limonene	Oxidised Forms are very allergic	Irritation of the skin, dermatitis, contact eczema due to air-oxidized limonene	Carcinogenic Class 3
FLAME RETARDANTS			
Hexabromocyclododecane	Neurotoxic	Possible Hormone Disruption	-
Polybromodiphenylethers	Neurotoxic		-
PHYSICAL			
Radon	-	Lung cancer	Carcinogenic Class 1
BIOLOGICAL	Respiratory Disorders	Respiratory Disorders	-
microbial contaminants			

Table 6: Pollutants: Sources and Concentration Ranges (*)

Pollutant	Source		Concentration Range	
	Outdoor	**Indoor**	**Outdoor**	**Indoor**
PARTICLES	Traffic/Specific industry	ETS/Domestic Activities/Heating	approximately 20-50 µg/m³	Comparable to outdoor, strong variations indoors
Diesel soot				
Black Smoke				
Suspended particles				
PM10				
PM2.5				20-30 µg/m³
COMBUSTION/INORGANIC GASES				
NO	Combustion of Fuel	Heating/Cooking/Geysers	11-170 µg/m³	12 – 130 µg/m³
NO2	Combustion of Fuel	Heating/Cooking/Geysers	19 -80 µg/m³	30-100 µg/m³
NOx	Combustion	Combustion	See NO/NO_2	See NO/NO_2
CO	Combustion	Combustion	0,05-57 mg/m³	290-1230 ppm
CO2	Combustion	Combustion	av. 620 mg/m³	Up to 5400 mg/m³
O3	Photochemical Oxidation	Penetration from outdoor	10-180 µg/m³	2-90 µg/m³
SO2	Combustion	Combustion	annual 20-60 µg/m³	1-22 µg/m³
PAH	Combustion	Combustion	1-10 ng/m³	<27-124 ng/m³
(S)VOC				
C10-C20 alkanes/alkenes/aromatics	27 % of NMVOC diesel engines	Product Emissions	n/a	n/a
TVOC (Total Volatile Organic Compounds)	Traffic/Industry/Heating	Product Emissions	20-650 µg/m³	300 - 1700 µg/m³
Benzene	Traffic/Industry	Product Emissions	1-20 µg/m³	2-30 µg/m³ (non smoking)
Toluene	Traffic/Industry	Product Emissions	5-150 µg/m³	20-74 µg/m³
Ethylbenzene	Traffic/Industry	Product Emissions	0.02-14 µg/m³	1-138 µg/m³

Pollutant	Source		Concentration Range	
	Outdoor	**Indoor**	**Outdoor**	**Indoor**
Xylenes	Traffic/Industry/Insecticides	Paints/Glues/Lacquers	2-20 µg/m³	7.8-37 µg/m³
1,2,4-Trimethylbenzene	Traffic/Industry	Product Emissions	<400 µg/m³	<4 µg/m³
Styrene	Polyester production	ETS/lag	1-10 µg/m³	1-6 µg/m³
p-dichlorobenzene	-	Disinfectants/Insecticides/ deodorants	<0,6 µg/m³	2-240 µg/m³
1,1,1-Trichloroethane	Metal Cleaning/Degreasing/..	No information	< 16 ppb	No information
Trichloroethene	Solvent/Chemical Intermediary	Degreasers/paints/Cleaning Products	generally 1-10 µg/m³	typically similar
Tetrachloroethene		Textile/Carpet/Dry cleaner's	generally less then 5 µg/m³	generally less then 5 µg/m³
Vinyl chloride	PVC production	Plastic	1-5 µg/m³	Up to 10µg/m³
pentane / cyclohexane / ethanol				
glycol ether, e.g. 2-butoxyethanol	Specific Industry/Traffic/Chemical Intermediary	Product Emissions	<19.6 mg/m³	< 8µg/m³
Butyl acetate	Specific Industry	Paints/Lacquer		
MTBE	Petrol additive	none	0.6-7 µg/m³	0,6-40 µg/m³
Formaldehyde	Diesel exhaust/Photochemistry/Wood- and textile industry	Furniture/Textile/Lag	1-20 µg/³	10-350 µg/m³
Acetaldehyde	Intermediary	Wood Panels	av circa 5 µg/m³	20-50 µg/m³
Acrolein	Transport	ETS/Burning of Animal Fat	<32 µg/m³	<80 µ/m³
Methylene diisocyanate	Production of Polyurethane Foam	Polyurethane Foam	No Information	No information
PESTICIDES/BIOCIDES				
Triclosan	Insecticides	Treated Wood/Carpet	No information	No information
Permethrin	Herbicides	Domestic Activities	<0.57 µg/g	<8.8 µg/g
TERPENES				

Pollutant	Source		Concentration Range	
	Outdoor	**Indoor**	**Outdoor**	**Indoor**
alfa-Pinene	Mainly biogenic/ some specific industry	Solvents/Deodorants/Paintings/Varnish	< 8 ppb	10-17 µg/m³
d-Limonene	Mainly biogenic/some specific industry	Solvents/Deodorants	< 32 µg/m³	15-30 µg/m³
FLAME RETARDANTS			<1.6 µg/m³	Low concentrations are to be expected
Hexabromocyclododecane	Specific Industry	Textile/Plastics		
Polybromodiphenylethers	Specific Industry	Textile/Plastics		
PHYSICAL				
Radon	Natural Rock Formations (soil emissions)	Construction Materials/ Soil emissions	10 Bq/m³	20 Bq/m³ - 100 Bq/m³
BIOLOGICAL	-	Pets/molds		
microbial contaminants				

(*)Table 6 will continuously be updated during the project as more literature information becomes available, updates available through website Flies (url: http://www.vito.be/flies)

Table 8 includes for the considered pollutants the WHO guideline values. These values are considered as the most widely accepted health based guideline values. Where thought relevant or in case no information was found, Table 8 is completed with either ambient or indoor air guideline values. In some cases also occupational hygiene values are included, knowing that these are in fact based on a 40 years/8 hours working period; these should therefore (at least) be divided by a factor of 10 for extrapolation to overall population health based guideline values. Some sources suggest to divide by a factor 40 (Salthammer 2005)
A description of abbreviations, used in Table 8, is given in Table 7.

Table 7: Guideline Abbreviations

Abbreviation	Organisation	Meaning
ALTER	Federal-Provincial Advisory Committee on Environmental and Occupational Health	Acceptable Long Term Exposure Range
PEL	Occupational Safety and Health Administration (OSHA)	Permitted Occupational Exposure Limits
REL	National Institute for Occupational Safety and Health (NIOSH)	Recommended Occupational Exposure Limits
TLV	American Conference of Industrial Hygienists(ACGIH)	Occupational Treshold Limit Value

Table 8: Guideline Values

Pollutant	**WHO/Others**	
	Guide value	**time**
PARTICLES	Dose - Response	-
Diesel soot		
Black Smoke		
Suspended particles		
PM10	40 µg/m³ (EC)	year
PM2.5	ALTER: 40 µg/m³ (Canada)	
COMBUSTION/INORGANIC GASES		
NO		
NO2	200 µg/m³ (WHO)	1 hour
NOx	30 mg/m³ (WHO)	1 hour
CO	10 mg/m³ (WHO)	8 hour
CO2	ALTER: 6300 mg/m³ (Canada)	
O3	120 µg/m³ (EC)	8 hours
SO2	125 µg/m³ (WHO)	24 hours
PAH *B(a)p*	8.7×10^{-2}	-

Pollutant	WHO/Others	
	Guide value	**time**
(S)VOC		
C10-C20 alkanes/alkenes/aromatics		
TVOC (Total Volatile Organic Compounds)	200 µg/m³ (Flemish indoor Decree)	
Benzene	5 µg/m³ (EC) $4 \times 10^{-6(a)}$	annual
Toluene	0,26 mg/m³ (WHO)	1 week
Ethylbenzene	22 mg/m³ (WHO)	1 year
Xylenes	0,87 mg/m³ (WHO)	1 year
1,2,4-Trimethylbenzene	PEL 120 mg/m³ (OSHA)	8h
Styrene	0,26 mg/m³ (WHO)	1 week
p-dichlorobenzene	134 µg/m³ (WHO)	1 year
1,1,1-Trichloroethane	PEL 1900 mg/m³ (OSHA)	8h
Trichloroethene	5000 µg/m³ (WHO) $4.3 \times 10^{-7(a)}$	long-term
Tetrachloroethene	0,26 mg/m³ (WHO)	annual
Vinyl chloride	TLV 20 mg/m³ (ACGIH) $1 \times 10^{-6(a)}$	8h
pentane / cyclohexane / ethanol		
glycol ether, e.g. 2-butoxyethanol	13 mg/m³ (WHO)	8h
Butyl acetate	PEL 710 mg/m³ (OSHA)	8h
MTBE	TLV 180 mg/m³ (ACGIH)	8h
Formaldehyde	0,1 mg/m³ (WHO)	30 minutes
Acetaldehyde	50 µg/m³ (WHO) $(1.5–9) \times 10^{-7(a)}$	1 year
Acrolein	50 µg/m³ (WHO)	30 minutes
Methylene diisocyanate	REL 0,05 mg/m³ (NIOSH)	8h
PESTICIDES/BIOCIDES		
Triclosan	No information	
Permethrin	No information	
TERPENES		
alfa-Pinene	TLV 112 mg/m³ AC(GIH)	8h
d-Limonene	No information	
FLAME RETARDANTS	Some Prohibited	
Hexabromocyclododecane		
Polybromodiphenylethers		
PHYSICAL		
Radon	-	-
BIOLOGICAL		
microbial contaminants		
(a) Lifetime cancer risk at 1 µg/m³		

5.3 Selected Pollutants: Measurement Methods and Strategy

5.3.1 Selection of the Pollutants

An important objective of the project is to actually measure the indoor/outdoor relation, and related concentration levels for a selection of compounds. The scope of the project also includes a number of limitations regarding the choice of pollutants. Compounds, only emitted from indoor sources will not be retained. Only pollutants from general sources (e.g. traffic, non-specific industry, heating, etc.) will be included.
Furthermore, the selection of pollutants takes into account compounds that were already included in other studies conducted in Flanders.

This leads to the following preliminary exclusions:

- Flame Retardants: measured in a VMM study (Bleux 2004);
- SO_2: not a key environmental issue in Flanders anymore;
- Biological agents: mainly an indoor problem;
- Electromagnetic Fields: a study is being conducted by G. Decat (VITO);
- Radon: this topic is a covered by the Belgian Nuclear Research Centre (SCK-CEN);
- Ozone: mainly specific Indoor Sources. Outdoor infiltration contributes also to the indoor concentrations, but in the winter season outdoor concentrations are relatively low and ozone has fast decay rates.

Apart from these exclusions, it was decided to sample compounds from each "main type", namely: particulate matter, combustion products, and a selection of VOC's.
For particulate matter, the PM fractions will be monitored, being PM10, PM2.5 and PM1.

Based on the list of priority pollutants formulated in the JRCs INDEX - project, the category of combustion products is furthermore narrowed to CO and NO_2. Taking into account the scope of this project, it was decided to retain NO_2 and to drop CO since this pollutant has very specific indoor sources and has merely peak exposure problems regarding health. PAH's will not be measured in this study because of the specific measurement methods required.

Within the category of VOC's a selection is made, based on health effects, literature (principally governmental such as the INDEX-project, the Flemish decree on indoor policy, etc..) and the feasibility of their respective measurement methods. Due to their specific, and expensive, measurement methods, terpenes, pesticides and bromated flame retardants will not be measured in this first Flemish indoor exposure study.
It was decided to measure benzene, toluene, ethylbenzene, styrene and the xylenes, which are not only easily measured, but also prioritised compounds in several legislative documents and studies. Formaldehyde also has the highest priority in the INDEX- project and is here included, as well as acetaldehyde since it is specified in the Flemish indoor legislation and in ISO 16000-3.
Also, the other VOC's specified in the Flemish decree are included in the study, namely trichloroethene and tetrachloroethene.
1,2,4-Trimethylbenzene and p-dichlorobenzene are measured based on their selection in EXPOLIS, INDEX, ISO-16000-1. TVOC (C_6-C_{16}) will be included too.

Methyl Tertiary Butylether (MTBE) is also included in this study. Not only there are known health effects, but it also has no known indoor sources. The main outdoor source are automobile exhaust since it is used as a gasoline additive. Therefore it can be used as a tracer. Tracers are (chemical) compounds that generally can easily be measured and are used to follow processes of interest. In this study MTBE will be used as an indicator for the infiltration/ventilation of outdoor air into the indoor environment (GOELEN 2002).

If we balance this selection to the health effects known and described in paragraph 5.1, all compounds with a IARC carcinogenic classes 1 or 2 (except for vinyl chloride) are included. This selection also includes most of the compounds with acute and severe chronic health effects.

Al together this gives the compounds in the table below.

Table 9: Selected Pollutants for the FLIES Study

Compound	Measurement Method
PM (1, 2.5, 10)	Grimm
Formaldehyde Acetaldehyde	Diffusive sampling (DNPH impregnated) followed by GC-MS
NO_2	Diffusive sampling (TEA (or other) impregnated) followed by IC
TVOC	Diffusive sampling (active charcoal) followed by GC-MS (full scan)
Benzene, Toluene, Ethylbenzene, Xylenes, Styrene, 1,2,4-Trimethylbenzen, p-dichlorobenzene, trichloroethene, tetrachloroethene and MTBE	Diffusive Sampling (active charcoal) followed by GC-MS (SIM)

5.3.2 Measurement Methods

a) Volatile Organic Compounds (VOC)

Individual and total volatile organic compounds are adsorbed on activated charcoal, solvent desorbed and analysed by means of a GC coupled to a mass-spectrometer (GC/MS).
The samples in the micro-environments will be taken with high uptake rate diffusive samplers manufactured by e.g. Radiello. The laboratory has experience with this type of sampler (e.g. FLEHS) and all parameters are well known. The typical sampling period can vary from eight hours up to 30 days. The sampler has been validated for 1 week use (e.g. MACBETH) and for 4 weeks use (SPRUYT 2004). In the NHANES project, Tom Stock of the Environmental Sciences department of the University of Texas School of Public Health, has validated methods for using the 3M passive badge for 48-72 hour sampling. After sampling, the dosimeters are collected in the laboratory for analysis. The samplers are extracted in the laboratory with carbon disulfide (CS_2). Analysis is performed on a HP5890 GC hyphenated with a HP5973 MS (or equivalent). TVOC is measured in full scan-modus, while the other compounds are measured in selected ion monitoring (SIM) mode. External standards are used for calibration.

b) Aldehydes

Aldehydes are sampled with diffusive dosimeters manufactured by e.g. Radiello or SKC. These samplers have been used and validated in laboratory and field experiments (Spruyt 2005). It is principally a chemisorption method where aldehydes react with dinitrophenolhydrazine (DNPH). The aldehydes are extracted with ethylacetate and analysed by GC-FID/MS or extracted with acetonitrile and analysed by LC-UV. Interference from other pollutants such as ozone and nitrogen dioxide is well known (ISO 2001). These effects and possible solutions have been thoroughly investigated in the CEC-FP4-SMT Aldehydes project.

c) Nitrogen Dioxide

Nitrogen dioxide is sampled with diffusive monitors from e.g. Radiello, Gradko, Ogawa or equivalent. After the extraction with ultra pure water, the samples are analysed with an ion-chromatograph from Dionex. A validation study has been conducted at VITO by order of the Flemish Environment Agency (VMM) (Swaans 2005).

d) Particulate Matter

Particulate matter will be measured with portable dust monitors manufactured by GRIMM or an equivalent monitor. It is a continuous measurement technique based on spectrometry. It is able to run during the same period as the other dosimeters. PM10, PM2.5 and PM1 can be measured simultaneously by means of the GRIMM monitor.

e) Quality Assurance

The VITO expertise centre “*Environmental Measurement*” has the capacity and the experience to perform the analysis of the samplers. The measurements will be performed following internal procedures. Most of the internal procedures are ISO-170025 accredited (Beltest Accreditation number: 058-T-ISO17025) or at the Belgian FPS Employment Labour and Social Dialogue (BS 2005012004). Furthermore, the expertise centre is reference laboratory in Flanders for environmental measurements and disposes as such of all accreditations from the Flemish government for environmental measurements.
Those procedures and experiences will be the basis for all sample handling. Field – and method blanks will be used to detect cross contamination, the calibrations are under strict control to obtain comparable results through the campaign and all data registration is fixed to have full traceability of all samples.
Whenever the quality control parameters go out of control, the ongoing analysis will be stopped. The results will only be reported for the samples concerned if a second analysis can be performed without the quality control parameters going out of control.

If a result is under detection limit, it will be reported as such. The value used in data interpretation will be the detection limit. The only effect of this method is an increased variation of the low level concentration samples. This means that certain statistical conclusions will be missed, but at least it will not lead to faulty statements.

5.3.3 Measurement Strategy

Considering the compounds and measurement methods chosen, 212 sets of measurements will be performed. The set of measurements includes all of the selected pollutants (Table 9). Logistics might be a problem for the sampling of particulate matter. Not only the availability of the dust monitors might be an issue, the availability of qualified personal to set up the measurements might interfere with the foreseen strategy. Therefore it is possible that we are forced to alter the measurement strategy for particulate matter during the measurement campaign and reduce the number of dwellings were particulate matter will be sampled.
Power calculations about the sample size have been done and can be found in annex 1 (section 9)
All measurements will be carried out in the winter season, as this provides the worst case scenario for exposure for most of the compounds. Formaldehyde levels for instance, might be higher due to the fact that emission increases with temperature.
The strategy is to calculate the exposure from measurements performed in 5 micro-environments, being dwellings, ambient air, school/day care, transport and leisure. The choice for these micro-environments is based upon the time-activity patterns of the children (section 2.1). Emphasis is put on dwellings for mainly two reasons. Children are spending most of their time in dwellings and there is possibly a larger variation than in some of the other micro-environments. A visual representation of the strategy is given in Figure 1.

The primary source of exposure are the dwellings. The dwellings will be chosen near hot spots (HS, 15000 transport movements a day), urban background (UB, (< 500 transport movements a day) and rural background (RB, (< 50 transport movements a day). In Flanders about 25 % of the population lives in cities. About 50 % lives in areas with a population density comparable to those of the smaller cities. In order to have a representative set of dwellings, 25 % of the dwellings are chosen in hot spots, 25 % in rural background regions and 50 % in urban background.
There will be measured for a period of one week (seven days). At one location, samples will be taken every day in order to compare the individual daily values with the seven days average. A total of 50 dwellings will be monitored. In each dwelling, indoor and outdoor samples will be taken.
The outdoor samples will be taken at a minimum distance of one meter from the house as specified in the ISO standards (ISO 2004). In the urban area, both front door and back door will be monitored, since differences in concentration levels are expected due to traffic. In the rural background area, only the back door will be monitored, since we expect a homogeneous distribution of the pollutants around the dwellings.
For the indoor measurements, the choice has been made to sample the dwellings' living room. In addition to that, an extra indoor measurement will be done in a selection of dwellings, namely all dwellings in rural area, and in urban hot spots and urban background 4 and 7 dwellings respectively. The extra sample will be taken in the sleeping room.

Another main activity and source of exposure are schools and daycares. Four schools and three day care centres will be sampled, respectively in hot spots, urban background (2 schools) and rural backgrounds

For leisure locations, only limited amount of samples will be included, since these are less relevant for exposure of children. Except for bars which might have a presence of tobacco smoke, but that is specifically not included in this study. Possible locations are library, shop, cinema and suchlike. Seven measurements are provided at these locations.

For transportation, ten measurements will be carried out. It has little use to determine indoor/outdoor relationships, there should be very few differences between the indoor and the outdoor air quality for most forms of transport. Outdoor air quality will be taken from relevant monitoring sites of the public monitoring network. Types of transportation suggested are cars, pedestrians, cyclists, buses and trams/metros. One of each will be sampled in urban and in rural areas.

A summary of the measurements that will be conducted is given in Table 10

Table 10: Summary of the Measurement Locations

Micro-environment		**Number of Locations**	**Number of Measurement Sets**
Dwellings (50 in total)	Hot spot	14	46
	Urban Background	23	76
	Rural Background	12	36
	Effect Time Averaging	1	24
Schools/Day Care		7	14
Transport		10	10
Leisure		7	7

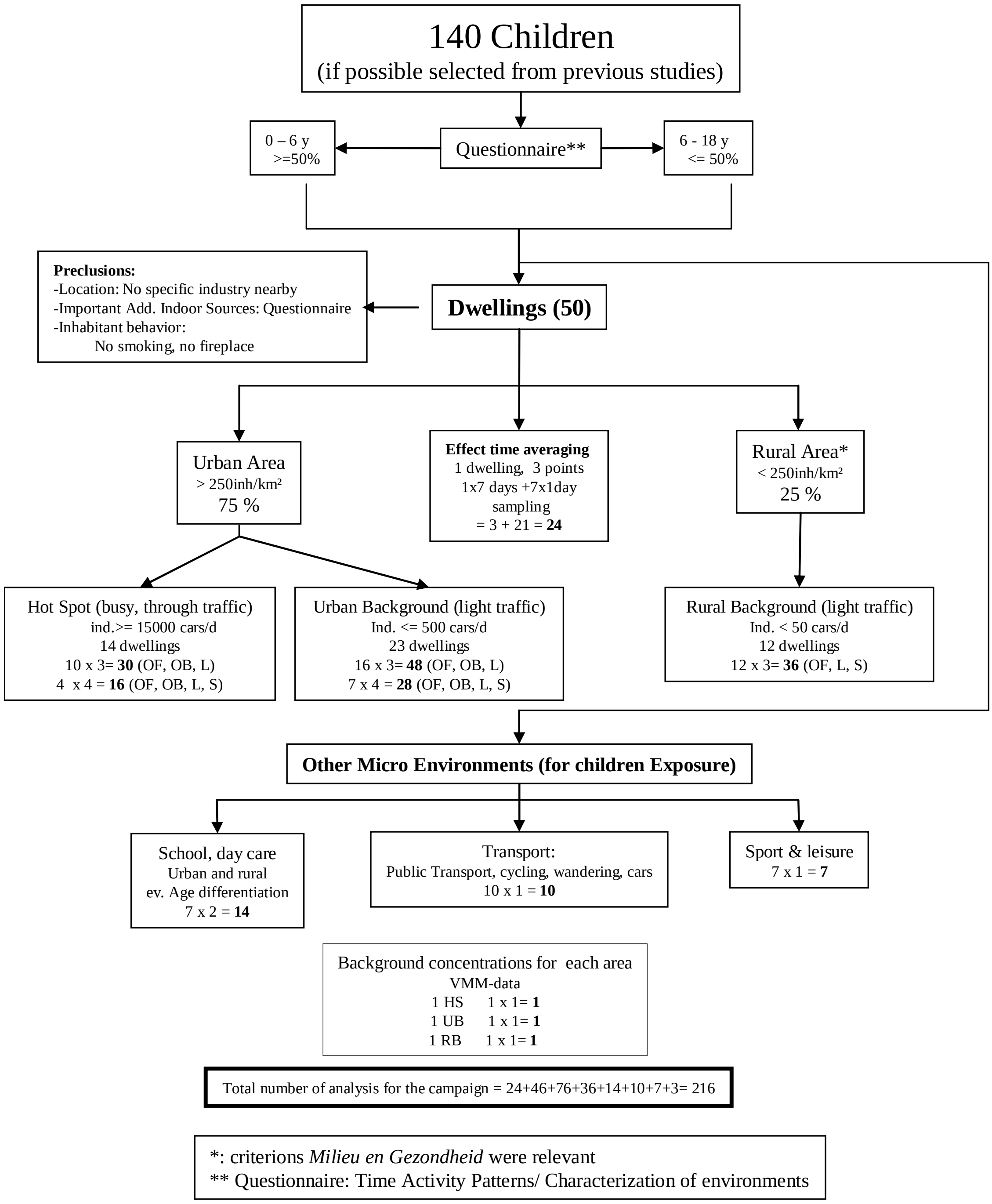

Figure 1 Sampling Diagram

OF: Outdoor, Front door;
OB: Outdoor, back door;
L: Living Room;
S: Sleeping Room;

6 SUMMARY OF THE OVERALL FINAL STRATEGY

The objectives of the study are:

1. the generation of data for Flanders on indoor exposure of children for a set of pollutants;
2. to determine the contribution of outdoor air pollution to the exposure indoors.

For the purpose of the Environment and Health administration of the Flemish Region, results have to be representative for Flanders. Within the optimal strategy described here, choices according to budget and preference of the steering group are made before starting the actual measurements (WP2). Possible suggestions of reviewers are also taking into consideration.

We follow a micro-environment/time activity approach. It means that measurements of representative micro-environments are linked with the time children spent there to calculate the exposure. Three important steps are therefore undertaken before staring the measurements:

a. A screening and selection of vulnerable groups of children, and their time-activity pattern that will dictate the micro-environments to be measured.
b. An analysis of the indoor environments that have to be included, and the relevant parameters that influence indoor exposure.
c. A screening and selection of relevant pollutants.

We will focus on the most vulnerable ages, 0-3 year and 3-6 year. Thus, measurements will be performed in homes (living room and/or bedroom), day-care or nursery schools and we'll keep track of the outdoor concentrations simultaneously. Next to the available literature data, time activity patterns will be enquired in detail for these age groups. Nevertheless we will use the measured data also to assess the exposure of children at other ages if sufficient information on time activity pattern and micro-environmental concentrations is available. The result will be an overview of indoor exposure for all age groups (0-18) of children in Flanders.
This point was raised by the steering group, and therefore indoor and outdoor measurements at schools are included in sufficient numbers (preferably old and new schools, and some of them close to intense traffic). Limited information is gathered for other micro-environments (shop, library etc.), to generate a first set of data on exposure for these environments in Flanders as well.
Although the focus in this study is on exposure indoors where children spent most of their time, i.e. in homes, day-care and schools, attention is given to 'in transport' situations, because of the increasing attention to traffic-related exposure, and to create also here a first set of data in Flanders. A number of exposures in an urban and rural environment are monitored: walking, cycling and routes by car or public transport are considered.

The relation between outdoor and indoor air pollution is governed by the concentration outdoor and the penetration level or filtering level of the building, the chemical adsorption or deposition indoors and the air exchange rate. We will measure the air infiltration/penetration factor of the dwellings by monitoring a pollutant (MTBE) that has only outdoor sources. Penetration levels for particles are assumed to be close to 1. Literature data of decay and deposition of pollutants, taking into account the life style and materials indoor via questionnaires. Manual ventilation is also asked. Ventilation

rates according to building standards and their distribution in Flanders is derived from existing literature.
To test a range of different outdoor situations the residential buildings will be selected in a high traffic density area (urban characteristics) and low traffic density area (rural characteristics). We want to avoid very specific industrial sources, and reject residences with smokers. In Flanders about 25 % of the population lives in cities. About 50 % lives in areas with a population density comparable to those of the smaller cities. We will use these numbers as an indication when choosing residential location in Flanders in order to have a representative set of houses.

From a practical point of view, the selection of the subgroups will be maximally synchronised with other ongoing environmental studies in children. This approach has the advantage that individual information that is already available (e.g. questionnaires, databases of external exposure in the past, etc.) can be used in the current study. Moreover, it reduces the practical work associated with recruitment. At the moment, a large bio-monitoring project in newborns (n=1200) is running in Flanders. Within this project, a subgroup of 140 children was included in a follow-up study on asthma and allergy. These children live in an urban area (Antwerp) or in a rural area (East- and West-Flanders). They are currently participating in a 3-year follow-up study. The mothers are contacted on a regular basis and provide information on nutrition of child and living conditions of the family. There is a good willingness to co-operate in further studies.
Possibly the homes of the participants are not representative for Flanders, if needed participants will be recruited exterior of the follow-up study population.

Pollutants considered are: nitrogen dioxide, PM, formaldehyde, acetaldehyde, TVOC, Benzene, Toluene, Ethylbenzene, Xylenes, Styrene, 1,2,4-Trimethylbenzen, p-dichlorobenzene, trichloroethene, tetrachloroethene and MTBE.

7 SURVEY OF RELATED NATIONAL AND INTERNATIONAL PROJECTS

The tables below provide additional information (summarized and with web links) for a selection of projects in the context of population exposure to air pollutants.
Mainly European research projects are listed, followed by Flemish projects that deal with child exposure. The European projects were executed within the Framework of various scientific programmes, such as e.g. Cafe, Framework Programmes, Life, …

Acronym	Date	Contact person	Short description	Internet address
International Projects				
AIRALLERG	2000 - 2005	B. Brunekreef	Multi-centre birth cohort study; comparison of environmental exposures between sensitised and non-sensitised children	http://www.iras.uu.nl/research/projects_env_and_health/eh06.php
AIR4EU	2006	Prof. Dr. Peter Builtjes	1) To formulate a guidance document on best practices for the combined use of monitoring methods and models to assess Air Quality in Europe from hotspot/street level to continental level for various users on local, regional, national and European level and for various purposes. 2) To prepare maps of air quality in Europe based on the available European wide data sets and best technique of assessment.	http://www.air4eu.nl/index.html
AIRNET	2005	B. Brunekreef	AIRNET is a network project initiated to develop an overarching European-wide framework for air pollution and health research. AIRNET collects, interprets and disseminates data from individual (EU-funded) projects, in order to strengthen the science policy interface and to draw policy-relevant recommendations	http://airnet.iras.uu.nl/

Acronym	Date	Contact person	Short description	Internet address
APHEA	1995	Klea Katsouyanni	i) To provide quantitative estimates of short-term health effects of air pollution, taking into consideration interactions between different pollutants and between pollutants and other environmental factors. This objective will be realised with the use of a very extensive data base from several different European countries which represent various environmental and air pollution situations. ii) To standardise the methodology in the analysis of epidemiologic time series data. This will involve detailed consideration of the methods used so far and suggestions for new approaches as well as standardisation of the exposure (air pollution) measurements and confounding factors to be controlled. iii) To select and develop a meta-analytic approach for epidemiologic time-series studies. iv) To assess the feasibility of creating a European data base of air pollution measurements and of health indicators, recorded on a daily basis. This will allow a continuous surveillance of short-term effects of air pollution in the future.	http://europa.eu.int/comm/research/success/en/env/0267e.html
APHEIS	2004	Sylvia Medina	Monitoring the Effects of Air Pollution on Health in Europe	http://www.apheis.net/
APMoSPHERE	2005	D. Briggs	EU-wide data sets on air pollution emissions, exposures, population - Air Pollution Modelling for Support to Policy on Health and Environmental Risk in Europe	http://www.apmosphere.org/
CLEAR	2003	Prof. Ranjeet S Sokhi	Cluster of European Air Quality Research	http://dev.allez.no/clear/

Acronym	Date	Contact person	Short description	Internet address
ESCODD	2003	Prof. Andrew R. Collins	The Role of food in promoting and sustaining health	http://www.rowett.ac.uk/escodd/
EUROHEIS	2004	L. Jarup	User networks; health impact assessment tools	http://www.euroheis.org/
EXPAH	2001 - 2003	P.B. Farmer	Effects of polycyclic aromatic hydrocarbons (PAHs) in environmental pollution on exogenous and endogenous DNA damage	http://airnet.iras.uu.nl/inventory/project.php?id=2
EXPOLIS	2004	Matti Jantunen	Air Pollution Exposure Distributions of Adult Urban Populations in Europe	http://www.ktl.fi/expolis/
FIRE	2002	Jeff Vos	The overall objective of this multi- and interdisciplinary project is to improve risk assessment of brominated flame retardants (BFRs) for human health and wildlife.	http://www.rivm.nl/fire/
GA2LEN	2004 - 2008	Bert Brunekreef,	Network of excellence in allergy and asthma	http://www.ga2len.net/hp/homepage2.cfm http://www.iras.uu.nl/
GEMS	-	D. Briggs / Michel Cornaert	Long-range air pollution transport models, and EO data sets - Global Monitoring for Environment and Security (GMES)	http://www.apmosphere.org/

Acronym	Date	Contact person	Short description	Internet address
GerES	1985-…	Umweltbundes-ambt	One of GerESs main objectives is to generate, update, and evaluate representative data in order to facilitate an environmental health related observation and reporting of information at the national level. • Up to 5000 subjects are questioned and analysed in every survey. The resulting data can also serve: • as a basis for establishing reference values, • to indicate trends over time and regional differences in contaminant levels, • to identify and quantify contamination routes. GerES thus makes it possible to design and evaluate preventive, interventive and control strategies within the framework of policy measures related to health and environment. GerES IV is conducted in cooperation with the National Health Survey for Children and Adolescents (KiGGS) that is conducted by the Robert Koch-Institute. Using data of both surveys (the Environmental and the Health Survey) it is possible to evaluate relations between environmental conditions and health of the children, e.g., between the occurrence of mould fungi in homes and allergies.	http://www.umweltbundesamt.de/survey-e/

Acronym	Date	Contact person	Short description	Internet address
HEAPSS	2003	Francesco Forastiere	The aim of the study is to determine whether exposure to ambient air pollution increases the risk of acute hospitalisation and the risk of mortality among population-based cohorts of patients who had survived a myocardial infarction (MI). Incident cases of non-fatal MI are recruited through ad-hoc population registries or from available records of hospital admissions in five European cities (Augsburg, Barcelona, Helsinki, Rome, Stockholm) with different air pollution levels and climate. Each subject will be followed for at least one year; outcomes of specific interest will be subsequent hospitalisation for secondary MI, arrhythmia, congestive heart failure or sudden deaths.	http://airnet.iras.uu.nl/inventory/project.php?id=59
HEARTS	2005	M. Martuzzi	Integrated health impact assessment model for road transport	-
HELIOS	1999	Alfred Bernard	Biomarkers for the non invasive assessment of acute and chronic effects of air pollutants on the respiratory epithelium. Development and Application to Adults and Children along a North-South European	http://airnet.iras.uu.nl/products/reports_and_annexes/HELIOS/HELIOS_final_report_Part_A.pdf
HYENA	2006	L. Jarup	Noise exposure and health effects data around airports	-

Acronym	Date	Contact person	Short description	Internet address
INDEX	2002	Dimitri Kotzias	The INDEX project (Critical Appraisal of the Setting and Implementation of Indoor exposure Limits in the EU) started in December 2002 and had a duration of two years, until December 2004. The project was financially supported by DG SANCO and it was coordinated and carried out by the JRC in collaboration with a Steering Committee of leading European experts in the area of indoor air pollution. Scope of INDEX was to identify priorities and to assess the needs for a Community strategy and action plan in the area of indoor air pollution by: - setting up a list of compounds to be regulated in indoor environments with priority on the basis of health impact criteria - providing suggestions and recommendations on potential exposure limits for these compounds, and - providing information on links with existing knowledge, ongoing studies, legislation etc. at world scale.	http://www.jrc.cec.eu.int/pce/pce_documentation.htm
MACBETH	1999	Vincenzo Cocheo	Environment and health - Benzene in the city	http://europa.eu.int/comm/research/rtdinf23/en/envir.html
NHANES	1999	U.S. Department of Health and Human Services Centers for Disease Control and Prevention, National Center for Health Statistics. : National Health and Nutrition Examination Survey		http://www.cdc.gov/nchs/about/major/nhanes/nhanes99-02.htm
PCBRISK	2004	Tomas Trnovec	Evaluating Human Health Risk from Low-dose and Long-term PCB Exposure	http://www.pcbrisk.sk/welcome_web.htm http://dioxin2004.abstract-management.de/pdf/p524.pdf

Acronym	Date	Contact person	Short description	Internet address
PEOPLE	2002 - 2004	Emile De Saeger	The Population Exposure to Air Pollutants in Europe	http://ies.jrc.cec.eu.int/Units/eh/Projects/PEOPLE/
PINCHE	2003 - 2006	Peter van den Hazel/Moniek Zuurbier.	Policy Interpretation Network on Children's Health and Environment	http://www.pinche.hvdgm.nl/
TEAM	1980s	Wallace	The Total Exposure Assessment Methodology (TEAM) was designed by the EPA to develop and demonstrate methods to measure human exposure to toxic substances in air and drinking water. The goals of Volatile Organic Compound (VOC) TEAM were to develop methods to measure individual total exposure (from air, food and water) and the resulting body burden of toxic and carcinogenic chemicals, and to apply these methods within a probability-based sampling framework to estimate exposures and body burdens of urban populations in several U.S. cities. To achieve these goals, air sampling was conducted to measure personal exposure to airborne toxic chemicals and a specially-designed spirometer was developed and used to measure the same chemicals in exhaled breath. The survey design consisted of a three stage stratified probability selection approach to ensure inclusion of potentially highly exposed groups. Related objectives of the VOC TEAM studies were to (i) determine the relationships between personal, indoor, outdoor, and blood, urine, and exhaled breath concentrations and (ii): determine the variability of VOC concentrations within a home;	

Acronym	Date	Contact person	Short description	Internet address
			and determine seasonal and multi-year variability. The Study was conducted in three phases were 2–5 times larger than median outdoor concentrations; maximum personal exposures were as much as 100 times corresponding maximum outdoor concentrations. Residence near major point sources had no effect on exposure but many common activities (filling a gas tank, visiting a dry cleaner, smoking) have significant effect on exposures.	
TRAPCA	2001	-	Risk assessment of exposure to traffic-related air pollution for the development of inhalant allergy, asthma and other chronic respiratory conditions in children	http://airnet.iras.uu.nl/products/reports_and_annexes/TRAPCA/TRAPCA_technical_annex_revised.pdf
ULTRA	-	Juha Pekkanen	The goal of the ULTRA project is to improve knowledge on human exposure to particulate matter of different sizes and of different chemical composition in Europe, and to evaluate the associated health risks. These results can then be used to develop standards for air quality in Europe, for better and more efficient monitoring of air quality, and as a base for designing control strategies to improve urban air quality and reduce the health effects associated with exposure to particulate matter in ambient air.	http://www.ktl.fi/ultra/

Acronym	Date	Contact person	Short description	Internet address
National Projects				
Pilot project 'Environment and Health' (Milieu en Gezondheid)	1999-2000	Prof. dr. R. Vlietinck	biomarker study in adolescents and adults in 3 regions in Flanders (urban vs. rural)	http://www.wvc.vlaanderen.be/gezondmilieu/index.htm
Biomonitoring 'Flemish Environment and Health Study (FLEHS)'	2001-2006	Prof. dr. G. Schoeters	biomarker study in newborns, adolescents and adults in 8 regions in Flanders	http://www.milieu-en-gezondheid.be/onderzoek/sd3biomonitoring/index.html
Neurological follow-up study	2001-2006	Prof. dr. M. Viaene	Neurological follow-up of newborns (neuropsychological development)	http://www.milieu-en-gezondheid.be/onderzoek/sd3neuropsycho/index.html
Immunological follow-up study	2001-2006	Consortium 'Steunpunt milieu en gezondheid'. Co-ordination: Prof. dr. K. Desager	Immunological follow-up of newborns (asthma and allergy)	http://www.milieu-en-gezondheid.be/onderzoek/sd4astma/index.html
Comparison and correlation of biomonitoring and environmental monitoring networks	2004-2006	Flemish Institute of Technological Research, Prof. G. Schoeters	1) Comparison of modelled and measured outdoor environmental imissions. 2) Association outdoor environmental data with personal dosimetry and biomarkers of adolescents participating in FLEHS.	

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9 ANNEX 1: SAMPLE SIZE CALCULATIONS ON VOC MEASUREMENTS

In this annex the number of samples is calculated necessary for a study to have the power to detect differences between groups. Theoretical sample size calculations were done based on real indoor and outdoor measurements of VOC's in two campaigns held in the cities of Antwerp (Cocheo 2000, Geyskens et al. 1999) and Mechelen (Goelen 2002).

Following formula was used to calculate the sample size needed to observe significant differences between two groups of observations (group 1 and 2):

$$n = \frac{\left(\sigma_1^2 + \sigma_2^2\right)\left(z_{1-\alpha/2} + z_{1-\beta}\right)^2}{\Delta^2}$$

with:

Δ: absolute difference between the mean of group 1 and 2;

σ_1: standard deviation of group 1;

σ_2: standard deviation of group 2;

$Z_{1\text{-alfa}/2}$ = 1,96 (if alpha=0,05)

> *Alpha: type I error. A level of significance of 5% is the rate you'll declare results to be significant when there are no differences between the groups. In other words, it's the rate of false positives (because samples of both groups show a difference just by chance;.*

$Z_{1\text{-beta}}$ = 0,84 (if beta = 0,2)

> *Beta: type II error. The chance you'll miss the difference (i.e. declare that there is no significant difference) when it really is there. In other words, it's the rate of false negatives.*
>
> *The usual Type II error rate is set to 20%. The power of the study is referred to as 80%. In other words, the study has enough power to detect the smallest worthwhile differences 80% of the time.*

Following table gives an overview of some sample size calculations done on VOC concentrations measured: (i) indoor and outdoor at different locations in Mechelen, (ii) indoor in Mechelen and in Antwerp. (Geyskens et al. 1999 and Goelen 2002).

With: SD=standard deviation, MC1= measuring campaign 1

Measurement	mean1	mean2	Delta	SD1	SD2	n
(i) Indoor and Outdoor Measurements: Different Locations of Mechelen						
BENZENE						
benzene **outdoor** (regional-urban) (µg/m3)						
Mechelen-MC1	1.8	2.5	0.7	0.2	0.6	**2**
benzene **outdoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	1.8	2.8	1.0	0.2	0.8	**3**
benzene **indoor** (regional-urban) (µg/m3)						
Mechelen-MC1	3.2	5	1.8	2.4	4.5	**1073**
benzene **indoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	3.2	5.7	2.5	2.400	5.500	**1189**
MTBE						
MTBE **outdoor** (regional-urban) (µg/m3)						
Mechelen-MC1	0.8	1.6	0.8	0.1	0.8	**5**
MTBE **outdoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	0.8	1.9	1.1	0.1	0.9	**4**
MTBE **indoor** (regional-urban) (µg/m3)						
Mechelen-MC1	0.9	3.9	3.0	0.2	5.6	**857**
MTBE **indoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	0.9	5.5	4.6	0.2	8	**1518**
TOLUENE						
toluene **outdoor** (regional-urban) (µg/m3)						
Mechelen-MC1	3.9	8.6	4.7	0.4	3.3	**42**
toluene **outdoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	3.9	10.4	6.5	0.4	4	**48**

Measurement	mean1	mean2	Delta	SD1	SD2	n
toluene **indoor** (regional-urban) (µg/m3)						
Mechelen-MC1	10.4	39.7	29.3	8.2	26.6	**4613**
toluene **indoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	10.4	16.4	6.0	8.2	7.2	**1570**
ETHYLBENZENE						
ethylbenzene **outdoor** (regional-urban) (µg/m3)						
Mechelen-MC1	1	1.7	0.7	0.1	0.5	**1**
ethylbenzene **outdoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	1	2.1	1.1	0.1	0.7	**2**
ethylbenzene **indoor** (regional-urban) (µg/m3)						
Mechelen-MC1	1.7	6.4	4.7	0.8	7	**852**
ethylbenzene **indoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	1.7	2.8	1.1	0.8	1.2	**16**
m-p-XYLENE						
m-p xylene **outdoor** (regional-urban) (µg/m3)						
Mechelen-MC1	2.4	3.9	1.5	0.3	1.1	**5**
m-p xylene **outdoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	2.4	4.9	2.5	0.3	1.5	**6**
m-p xylene **indoor** (regional-urban) (µg/m3)						
Mechelen-MC1	4.2	15.7	11.5	2.3	21.8	**13391**
m-p xylene **indoor** (regional-busy main street) (µg/m3)						
Mechelen-MC1	4.2	6.8	2.6	2.3	3.5	**206**
o-XYLENE						
o-xylene **outdoor** (regional-urban) (µg/m3)						
Mechelen-MC1	0.8	1.3	0.5	0.1	0.4	**1**

Measurement	mean1	mean2	Delta	SD1	SD2	n
o-xylene **outdoor** (regional-busy main street) (µg/m3) Mechelen-MC1	0.8	1.6	0.8	0.1	0.6	**2**
o-xylene **indoor** (regional-urban) (µg/m3) Mechelen-MC1	1.3	5.5	4.2	0.5	7.5	**1406**
o-xylene **indoor** (regional-busy main street) (µg/m3) Mechelen-MC1	1.3	2.4	1.1	0.5	1.5	**33**

(ii) Indoor Measurements: Antwerp (Macbeth) vs. Mechelen

BENZENE						
benzene **indoor:** Antwerp vs regional Mechelen	8.7	3.2	5.5	6.2	2.4	**392**
benzene **indoor:** Antwerp vs urban Mechelen	8.7	5	3.7	6.2	4.5	**1081**
benzene **indoor:** Antwerp vs busy main street Mechelen	8.7	5.7	3.0	6.2	5.5	**2084**
TOLUENE						
toluene **indoor:** Antwerp vs regional Mechelen	30.5	10.4	20.1	17.4	8.2	**1867**
toluene **indoor:** Antwerp vs urban Mechelen	30.5	39.7	9.2	17.4	26.6	**54864**
toluene **indoor:** Antwerp vs busy main street Mechelen	30.5	16.4	14.1	17.4	7.2	**3721**
ETHYLBENZENE						
ethylbenzene **indoor:** Antwerp vs regional Mechelen	6.4	1.7	4.7	9.4	0.8	**2771**
ethylbenzene **indoor:** Antwerp vs urban Mechelen	6.4	6.4	0.0	9.4	7	
ethylbenzene **indoor:** Antwerp vs busy main street Mechelen	6.4	2.8	3.6	9.4	1.2	**4724**

Measurement	mean1	mean2	Delta	SD1	SD2	n
m-p-XYLENE						
m-p-xylene **indoor:** Antwerp vs regional Mechelen	13.11	4.2	8.9	11.7	2.3	**1853**
m-p-xylene **indoor:** Antwerp vs urban Mechelen	13.11	15.7	2.6	11.7	21.8	**285863**
m-p-xylene **indoor:** Antwerp vs busy main street Mechelen	13.11	6.8	6.3	11.7	3.5	**3719**
o-XYLENE						
o-xylene **indoor:** Antwerp vs regional Mechelen	4.5	1.3	3.2	3.5	0.5	**115**
o-xylene **indoor:** Antwerp vs urban Mechelen	4.5	5.5	1.0	3.5	7.5	**25983**
o-xylene **indoor:** Antwerp vs busy main street Mechelen	4.5	2.4	2.1	3.5	1.5	**276**

It was concluded that:

- Ten or less samples is (mostly) enough to observe differences in outdoor VOC concentrations between two groups (cities or locations of the city);
- Large amounts of samples are needed to observe statistical significant differences in indoor VOC concentrations of two groups (cities). This is mainly due to the large concentration range (high SD) of the indoor measurements;
- Our study will focus on the relationship between outdoor and indoor concentrations. In this context variation gives an added value. The main influencing factors will be asked/controlled for/by in questionnaires. However, to exclude unnecessary confusing variation, sampling will not be done in houses of smokers, or houses with open wood fire or ongoing restoration work.