

Swedish National Air Pollution and Health Effects Program – SNAP –



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Introduction

Health effects from air pollution have again emerged as an important public health issue, in spite of decades of successful work in Sweden and elsewhere to decrease emissions, especially from oil and coal combustion. Evidence is accumulating that also the relatively low levels of air pollution present in Sweden need to be further lowered in order to prevent respiratory and cardiovascular diseases, and maybe even premature death (Bellander *et al* 1999). The complex content mixture of ambient air pollution and the diverse health effects involved emphasize the need for a multidisciplinary approach in this scientific research field. Furthermore, a close interaction between science and policy makers is needed for a successful preventive public health work, which motivates national support for the development of an integrated air pollution and health research program.

Air pollution includes many different components, e.g. particles, ozone, and nitrogen dioxide, that may contribute to a variety of health effects (Hemminki and Pershagen 1994, Pershagen *et al* 1995, Nyberg *et al* 2000, Svartengren *et al* 2000). The health effects related to air pollution in previous studies have mainly been respiratory and cardiovascular disease, but also cancer has been associated with air pollution (Hemminki and Pershagen 1994, Nyberg *et al* 2000). Generally, epidemiologic air pollution research has to a large extent been focused on mortality and morbidity, especially related to airborne particles, and in the last decade particularly on time-series studies investigating short-term elevations in particle levels. A number of studies, both experimental and epidemiological, have been conducted in order to investigate possible mechanisms and a summary of the current state of the science was recently published (Pope 2000). A large number of studies have shown associations between day-to-day variations in air pollution levels and increases in hospital admissions and mortality in lung- and heart disease (Bellander *et al* 1999). Most of these have been performed in urban areas with higher pollution levels than Swedish cities, but the few studies performed in Sweden and at similar exposure situations elsewhere also show adverse health effects.

In a Swedish study of acute health effects in a group of asthmatics exposed to air pollution in a road tunnel, an increased reaction after allergen challenge was observed, manifested as increased symptoms of asthma, and greater late phase pulmonary reaction (Svartengren *et al* 2000). The findings indicate that exposure to car exhausts initiates an inflammatory process in the bronchial mucosa. Previous studies have suggested that urban air pollution may be a risk factor for lung cancer, with estimated relative risks in the order of up to about 1.5 in most situations (Pershagen 1990, Hemminki and Pershagen 1994, Katsouyanni and Pershagen 1997). The results from a recent study on lung cancer in Stockholm indicates that long-term exposure to urban air pollution increases the risk for lung cancer and that vehicle emissions may be particularly important (Nyberg *et al* 2000). Also occupational exposure to similar pollutants (diesel exhaust, combustion products) was shown to increase the risk (Gustavsson *et al* 2000). In addition, exposure to combustion products in occupational settings was associated with an increased risk for myocardial infarction, and exposure to motor exhaust also indicated an excess risk (Gustavsson *et al* 2001).

Quantitative environmental risk assessment

Quantitative environmental risk assessment based on epidemiological findings is of crucial relevance for setting priorities in preventive public health work. Such health impact assessment for air pollution has mainly been performed for mortality, hospitalization, and exacerbation of asthma. Previous work show that estimates of population exposures may be used together with exposure-response functions to assess health impact from air pollution in regions or whole countries (Bellander *et al* 1999, Johansson *et el* 1999, Künzli *et al* 2000,

Bellander 2001a). Other important contributions come from the calculation of population attributable risks, such as in the study of lung cancer in Stockholm (Nyberg *et al* 2000). However, several issues remain to be addressed, in particular for assessment of exposure and health effects from aerosols. The perspective needs to be broadened and a number of methodological problems need to be solved.

Some of the outstanding issues in health impact assessment were recently discussed in a WHO workgroup meeting (manuscript in preparation), which gave the following recommendations:

1. The most complete estimates of attributable numbers of deaths and average reductions in life span are those based on cohort studies. However, only three such studies are at present available, all from North America.
2. Time-series studies are valuable for demonstrating and documenting effects of pollution, quantifying effects of short-term changes in pollution, and serving as a basis for pollution alert systems. However, impact estimates based on time-series studies tend to underestimate real impact of pollution, and do not reflect reduction of life span due to the pollution.
3. Health impact assessments should exercise great care when the evidentiary and target populations differ. In general, the most precise, valid and specific effect estimate should be used for impact assessment. Sensitivity analysis should be used to assess the possible impact of the differences in the populations.
4. Research is needed in the following areas to improve the scope and reliability of health impact analysis: chronic effects of pollution, determinants of variation in health response to an exposure between various populations, specific research to target populations, and generalization to other populations.

In order to advance the knowledge base for health impact assessment, the population exposures need to be better characterized, with particular attention to partial contributions from different sources. In addition, different aspects of exposure, such as long- vs. short-term exposure assessments, intensity of exposure, duration of exposure, cumulative dose, and different time windows for individual exposure, also need to be further explored. Susceptible individuals and population subgroups should be identified. Novel analytical techniques need to be implemented for analysis of the contributions of different exposure time domains to observed health effects, which can provide a basis for estimation of the public health impact of ambient air pollution. The biological mechanisms should be elucidated as well as important interactions for air pollution-related health effects.

The program's contribution to national and international prevention strategies

For this program to be successful in terms of providing what the national, regional, and local authorities need for their regulatory and preventive work related to air pollution, a continuous dialogue is required. The setting of new guidelines, and environmental quality standards according to the Swedish national aims for the environment, requires research in relevant areas. Topics of particular interest to the Swedish EPA include quantitative data on health effects from air pollution, relations between personal exposure and ambient concentrations, and the importance of source-specific exposure (i.e. road traffic, wood burning), and different aspects of exposure (i.e. maximum or average levels, short-term or long-term exposure). Improved knowledge and risk assessment for different pollutants is also pertinent for future regulation.

Because national air pollution levels also are partly dependent on emissions in neighbor countries, participation in the international discussions is important. It should be recognized that long-range transboundary air pollution problems are of importance also for the Swedish research and abatement activities. Future guidelines and agreements to reduce emissions, both within the European Union and elsewhere also affect Swedish air pollution politics and industry. For this program to make a contribution to future prevention strategies, it is thus also important to interact with the international synthesis and assessment activities organized by e.g. WHO, the EU Commission, and the U.S. EPA and Health Effects Institute. Therefore, scientific knowledge gained from this program should provide essential support for both national and international policy work, and be used in revisions of air quality standards and future EU directives. The Swedish EPA thus requires research specifically targeted on questions originating from the revision of air quality standards within the European Union. Such possible issues include to better characterize particle exposure in Sweden, to identify the toxic fraction or constituents of particulate matter in Swedish urban air, and to define sensitive subgroups within the Swedish population.

Recently, the EU Parliament and the Commission proposed a Community Environment Action Program for 2001-2010 (6th EAP, presented 13 June 2001). In Article 6 regarding environmental health and quality of life, the following objectives and priorities concerning air quality were stated:

- Achieving levels of air quality that do not give rise to significantly negative impacts and risks to human health and the environment.
- Re-examination, development and updating of current health standards and limit values, including where appropriate, the effects on potentially vulnerable groups, e.g. children or the elderly, and the synergies and reciprocal impact of various pollutants.

An important initiative for the coming years is the CAFE program (Clean Air for Europe) aiming to achieve political goals for the environment in Europe. The intention is that CAFE should develop into a five-year policy cycle, with the first integrated clean air strategy being adopted in 2004. A part of the strategy will be proposals for revisions of the air quality directives mainly for nitrogen oxides and particulate matter and the emission ceiling directives. The CAFE program is a thematic strategy to strengthen a coherent and integrated policy on air pollution, to cover priorities for further actions, and to review and update air quality standards and national emission ceilings. The aim is to reach the long-term objectives of no-exceedance of critical loads and levels, and to develop better systems for gathering information, modeling and forecasting. It is therefore important that the Swedish National Air Pollution and Health Effects Program (SNAP) take part in the international synthesis and assessment activities organized by WHO, HEI and the European Commission and disseminate results from the projects within “SNAP”. Initiatives to organize international workshops in Sweden will be taken.

The most important work during the period 2001-2004 within the European Commission will be the revision of the Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and lead in ambient air. Priority is given to particulate matter, but also nitrogen dioxide is of certain interest. The main focus will be the revision of the present PM₁₀ limit value and the possible introduction of a limit value for PM_{2.5}. Fine and ultra-fine particles will also be discussed.

In the report from the Committee on Environmental Objectives (SOU 2000:52) and the Government Bill on Swedish environmental goals (Proposition (2000/01:130) and for the objectives and targets for Clean Air, certain levels are given which should not be exceeded within a generation (20 years). These are given for benzene, PAH, ben(s)a)pyrene, ethene, formaldehyde, particulate matter, PM₁₀, black smoke, and ozone. Improved knowledge and risk assessment for these pollutants are important, and especially for fine and ultra-fine particles. There is an intermediate proposed target for nitrogen dioxide, which should be met 2010, and an intermediate target for PM_{2.5} established no later than year 2005. For these intermediate targets it is necessary to re-evaluate the health effects of nitrogen dioxide and PM_{2.5} not later than 2003/2004.

Below is a preliminary timetable for activities from SNAP in relation to the political agenda for the European Union and the Swedish EPA.

Table 1. Requirements from the Swedish EPA and the European Commission (COM)

Institutional activity	Support needed	SNAP activities (project; date)
EU – COM/CAFÉ		
– Revision of directive 1999/30/EC, to be reported from COM in 2003/2004.	Take an active part in this work, especially together with WHO during the period 2001-2005.	Continuous exchange of information with Swedish EPA officials.
Swedish EPA		
– Implementation of EU directive on benzene 2002.	Evaluation of health effects by 2002.	Interaction with working groups
– Bases for action plan for wood smoke emission 2003.	Exposure characterization and evaluation of health effects.	Progress report on wood smoke exposure
– New air quality standard for formaldehyde, anticipated to 2003.	Bases for risk assessment for formaldehyde in 2002/2003.	Interaction with working groups
– New air quality standard for 1,3-butadiene, anticipated to 2003.	Bases for risk assessment for 1,3-butadiene in 2002/2003.	Interaction with working groups
– New air quality standards for PM in 2005.	Bases for risk assessment for PM in 2003/2004.	Progress report on exposure and health effects from PM (2003)
– New air quality standard for NO ₂ in 2005.	Basis for risk assessment for NO ₂ in 2003/2004.	Progress report on exposure and health effects from NO ₂ (2003)
– Development of strategies for future air quality standards.	Basis for integrated air quality management.	Interaction with working groups, Final report (2006)

Preparedness for changes in the political agenda and new requirements from the Swedish EPA or others will be ascertained by a close interaction between the scientists and policy makers, and the opportunity to allocate financial support though a free funding part within this program.

Aims

The principal scope of the proposed program, “SNAP” – hence referred to as the *Program*, is to provide new information pertinent to the quantitative risk assessment of adverse health effects from air pollution. The information will be useful in the development of national and international guidelines as well as other preventive measures both on local and global scales. A secondary scope of the *Program* is to create and improve co-operation among national research teams within the field of air pollution. Thus, great effort will be given to repeated communication and possibilities for interaction with national, regional and local authorities,

institutions, and industry, as well as with other researchers. The *Program* will also promote training of researchers and experts in this field, and thus contribute to a high quality of the research on environment and health in Sweden.

The *Program* will specifically aim at addressing the following issues:

- ❑ To develop, improve and validate models for exposure assessment in epidemiologic air pollution studies.
- ❑ To evaluate the health effects associated with different pollutants in urban air, and quantitatively assess the risk for various health outcomes related to different air pollutants.
- ❑ To estimate the national public health impact of exposure to ambient air pollution.
- ❑ To explore different aspects of exposure to air pollution on health, e.g. different dose metrics and time-windows of exposure.
- ❑ To study the impact on health outcomes in both single- and multi-pollutant models.
- ❑ To identify susceptible subgroups for health effects from air pollution.
- ❑ To investigate potential interactions with other factors in relation to health effects from air pollution.
- ❑ To elucidate some biological mechanisms for an association between air pollution and various health outcomes.
- ❑ To produce, disseminate, and communicate valid and high quality data on air pollution and health to be used by national, regional, and local authorities and others in their preventive public health work.
- ❑ To promote co-operation and integration between Swedish research groups, and promote their involvement in international collaborations.

Program overview

The *Program* builds on future and ongoing research in participating centers and covers characterization of the human exposure to air pollution from different sources, and quantification of health effects, all aiming at facilitating risk assessment. It is focused on the general public, with special attention to populations at elevated risk – because of high vulnerability or high exposure levels. Important additional information on mechanisms will be generated in controlled experiments. The *Program* will have a multidisciplinary character, with involvement of leading Swedish groups in the field of air pollution and health. The work at each center will be performed in distinct projects, mostly with shorter time frames than the *Program* as such. Some of the projects in the *Program* have full or partial funding already available. Even fully funded projects are included in order to present an integrated view of the research activities. To further assure that the *Program* is comprehensive, also other leading researchers in the air pollution field will be stimulated to contribute with own projects by reserving a substantial part of the funding to a “free funding part”, as described further on in this research program application. Great care will be taken to develop interaction and synergism between all projects within the *Program*, regardless of funding status.

In summary, the activities outlined in the proposed research program will serve to improve the potential for risk assessment in the general population, with particular emphasis on urban air pollution at moderate levels as found in our country. They will fill important gaps in the international basis for risk assessment, and may be directly applied in preventive efforts in Sweden. Data on population exposures, health risk estimations, and variability in sensitivity derived from these projects will also add substantially to the basis of cost-benefit analysis. In particular, the *Program* will address the issues of sensitive individuals and subgroups, and how the effects on different diseases depend on high-pollution “episodes” or the average level

over longer periods of different pollutants. It will contribute to understanding what aspects of exposure are important, what pollutants should be measured and controlled. The *Program* will greatly enhance the possibilities of estimating the population exposure levels. It will determine social and biological factors that influence vulnerability to air pollution and will identify the special needs of defining high-risk groups. In order to facilitate an integrated approach to risk management, the *Program* will provide information for risk assessment and enable prediction of the health impact of air pollution at the population level. Thus, the activities planned within the *Program* can be considered to largely cover the requirements from the authorities involved in air pollution regulation and public health prevention, as previously mentioned. However, certain demands may still be beyond the scope of the projects included in the *Program*, while others may arise during the course of the *Program*. Therefore, specific projects may be called for when allocating resources from the free funding part of the *Program*.

Table 1 below provides a summary of the different single projects included in the *Program* to date. Some additional projects might be included further on, as well as studies originating from the free funding part. In the following program text, the single projects will be referred to using the project titles from the first column of this table, in quotation marks. The appendix following this program application provides detailed descriptions of all projects. For this purpose, the Swedish EPA application form for single projects has been used.

Table 2. Summary and short description of research projects included in the proposal for a Swedish National Air Pollution and Health Effects Program (SNAP).

No	Project title	Project description	Classification*	PI†	Inst‡
1.	“AIRALLERG”	Outdoor and indoor air pollution and allergy in children.	E,Q,V	TB	MME
2.	“PASTA”	Particles in Stockholm air – emission, distribution, and health effects with dose-response relations.	E,Q	TJ	SLB
3.	“Wood smoke exposure”	Exposure to air pollutants at domestic wood burning, a study before and after change to district heating.	E	LB	GBU
4.	“Personal butadiene”	A method for determination of personal 1,3-butadiene exposure.	E	LB	GBU
5.	“Personal PM _{2,5} exposure”	Personal exposure to fine particles, PM _{2,5} in the general population.	E	GS	GBU
6.	“Indoor/outdoor levels”	Investigation of the penetration of outdoor pollutants into homes of small children and child care units.	E	TB	MME
7.	“LEAP”	Long-term exposure to air pollution and myocardial infarction.	E,Q,V	GP	IMM
8.	“Cohort feasibility”	A study of the feasibility for a Swedish retrospective cohort study of air pollution and health.	E,Q,V	TB	MME
9.	“SENSI”	Acute health effects from air pollution in sensitive subgroups.	E,Q,V	TB	MME
10.	“HEAPSS”	Health effects of air pollution on susceptible subpopulations – database and health risk assessment.	E,Q,V	FN	IMM
11.	“ALVA”	Air pollution and life threatening ventricular arrhythmia.	E,Q,V	TB	MME
12.	“SALUT II”	Air pollution in a road tunnel and heart rate variability in adults, and bronchioalveolar lavage in asthmatics.	E,V	MS	KI
13.	“GIS-tool for exposure”	Development of tools for population-based exposure assessment and risk evaluation of air pollution.	E,Q	HW	LU
14.	“Software tool for exposure”	Development of a low cost software tool for exposure assessment for epidemiological and prediction studies.	E	KS	IVL

* E=Exposure quantification, Q=Quantative relation, V=Variability in sensitivity

† PI=Principle Investigator; TB=Tom Bellander, TJ=Tage Jonsson, LB=Lars Barregård, GS=Gerd Sällsten, GP=Göran Pershagen, FN=Fredrik Nyberg, MS=Magnus Svartengren, HW=Hans Welinder, KS=Karin Sjöberg

‡ Inst=Institution; MME=Department of Environmental Health, Stockholm County Council; SLB=Stockholm Air Quality and Noise Analysis; GBU=Göteborg University; IMM=Institute for Environmental Medicine, Karolinska Institutet; KI=Karolinska Institute; YME=Department of Occupational Health, Stockholm County Council; LU=Lund University; IVL=Swedish Environmental Research Institute

Models for exposure quantification

Air pollutants are traditionally measured in urban and rural background sites, and epidemiological studies have most often used data from centrally placed monitors for personal exposure assessment. This may introduce bias because of problems related to the representativity of the measured values to the whole study population, and the exposure measure can thus be considered as ecological only. Another complication is the difference between indoor and outdoor concentrations, which may differ substantially depending on e.g. ventilation, indoor scavenging, and chemical processes.

In a previous study designed to assess individual exposure to traffic related pollutants in the adult population of Stockholm County, NO₂ was monitored on 240 persons using small diffusion monitors (Almrén and Bellander 2000). The average individual NO₂ exposure ranged from 10 to 24 µg/m³ for different groups, which may be compared to the ambient air level (fixed monitors) of 19 µg/m³ for the same period. Average individual NO₂ exposure among adults living and working in central Stockholm was comparable to urban background monitoring levels. Living and working outside the center was, as expected, associated with lower NO₂ exposure. Contrary to expectation, the mode of transportation to work had little influence on the individual NO₂ exposure. In another study, fine particles (PM_{2.5}) were measured at 42 sites in Stockholm County, as a part of an extensive measurement program (Lewné and Bellander 2000). There was a tendency towards higher values at street locations compared with urban background, which was in turn higher than near-suburb and distant-suburb locations. Distant-suburb levels were on average low, and the lowest levels were in agreement with rural background measurements outside Stockholm County. In conclusion, these studies showed good agreement between the NO₂ level near the home and the individually measured level, and there was a comparatively good correlation between NO₂ and fine particles in different locations in the county. Limited data on personal sampling of selected air pollutants are also available from other parts of Sweden (Barregård 1999, Sällsten 2000, Loh 2001, Sällsten 2001). Several studies from the U.S. and Europe have shown higher levels of fine particles or benzene at personal exposure sampling than at stationary sampling outside homes or at urban background sites, as well as poor agreement between personal and stationary sampling (Ebelt 2000, Oglesby 2000 Wallace 1996, Pellizari 1999). Thus, the relation between personal exposure and measurements from fixed monitors in Sweden needs to be further explored, using compatible time domains, and the urban aerosol needs to be better characterized.

In the proposed program, the ambient exposure assessment focuses on environmental pollutants from road traffic and residential heating. The applicants and co-applicants have several ongoing projects to develop models for assessment of exposure to air pollution, partly based on international collaboration with funding from the European Union. Retrospective GIS-based estimation of exposure to air pollution generated by motor vehicles and residential heating have been obtained with reconstructed emission databases and dispersion modeling, and has proven useful for assessment of long-term effects of air pollution (Bellander *et al*

2001b). Current levels of exposure are estimated from dispersion modeling as well as from direct measurements, e.g. in ongoing projects measuring levels of particles, NO₂ and benzene in the environment (Lewné and Bellander 2000, Almrén and Bellander 2000). In the *Program*, the personal (and residential) levels will be measured for e.g. NO₂, soot, benzene, PAH, butadiene and aldehydes.

The use of emission data and dispersion models for exposure assessment purposes offers great possibilities for epidemiological studies. From a health viewpoint, airborne particulate matter is considered as one of the most important constituents of urban air pollution. The lack of data on the physical and chemical properties of urban particles has made it difficult to explain associations between particulates and various health effects, as observed in epidemiological studies. Of special interest is to continue the exploration of dispersion modeling of particulate air pollution, and to expand the current nation-wide urban measurement activities to include also smaller particulate fractions, PAH and other pollutants. The monitoring of particle mass should also be complemented with monitoring of particle numbers and estimation of particle surface area, PAH and other pollutants.

One of the projects in the *Program* is specifically designed to further develop and validate air pollution dispersion models (“PASTA”). The aim is to further develop and validate existing models so that they can be used to assess the temporal and geographical distribution of particulate matter in urban air in Stockholm. The project will also evaluate the relationships between PM (mass, number and surface area) and other air pollution and traffic parameters. Models for particulate matter will be developed and the air pollution monitoring will be expanded by setting up new monitors that will provide detailed characterization of the urban aerosol. Thus, particulate air pollution will be further characterized in order to better understand which are the important determinants of the health risks. The dispersion models will be used in integrated air quality management for assessing the air pollution exposure in the general population and potentially sensitive subgroups, as well as for retrospective exposure assessment in epidemiological health effects studies.

Monitoring of exposure and health risk assessment can be greatly facilitated with the use of computer aided tools such as GIS. In the *Program*, GIS will be used to establish a model for exposure assessment, which will be utilized to build a model for risk assessment for particles and NO₂ and to develop methods for biological monitoring of carcinogenic pollutants (“GIS-tool for exposure”). In another project in *the Program* a low cost software tool for air pollution exposure on a national level will be developed, which will be useful for exposure assessment in future epidemiological and prediction studies (“Software tool for exposure”). This project will further extend the “Urban model”, which was developed as a tool to assess if the Swedish air quality standards would be exceeded by applying monitoring data from e.g. around 100 towns. Comparisons will be made with the work on a GIS-tool for exposure assessment, and the software will be validated against the results from the personal exposure studies in *the Program*.

The indoor/outdoor relation needs to be further studied for several outdoor contaminants, and for houses with different ventilation systems. In one project in the *Program*, the particle fractions PM₁₀ and PM_{2.5}, as well as NO₂ will be measured inside and outside of 20 private dwellings, 10 day care units, and 10 schools (“Indoor/outdoor levels”). These will be chosen so that different types of ventilation systems are represented in the study. To estimate the annual average levels both indoors and outdoors of these pollutants, the measurements will be performed during three different months distributed over one year. Another project aims at

assessing personal exposure to PM_{2.5} both indoors and outdoors (“Personal PM_{2.5} exposure”). 24-hour measurements will be performed on 40 adult subjects. In yet another study, both outdoor and indoor air pollution will be assessed in a representative sample of children (“AIRALLERG”). The children’s exposure to specific outdoor air pollution components, e.g. diesel exhaust and NO₂, will be considered, and selected indoor pollutants, e.g. NO₂ and nitrous acid will be measured. Furthermore, several other indoor contaminants will be analyzed, e.g. environmental tobacco smoke, mould, mite, and pet allergens. These projects will provide a picture of how much air pollution adults and children are exposed to in their homes vis-à-vis the outdoors levels.

In Sweden, increased attention has in recent years been given to the negative effects of residential wood burning, mainly due to the many complaints to local authorities and concerns of health risks among those living in these rural areas. Despite the high contribution to the emission of particulate matter, PAH, and volatile organic compounds from wood burning in Sweden, there is a great lack of epidemiological data on individual exposure and health effects from domestic wood burning (Loh *et al* 2001). Studies from other countries are difficult to apply for Sweden, due to differences in climate, housing conditions, ventilation systems, and the use of air conditioning. In the *Program*, individual exposure to wood-smoke will be evaluated in an area in which district heating is introduced (“Wood smoke exposure”). Measurements of benzene, butadiene, formaldehyde, acetaldehyde, and PAH will be made in 60 randomly selected adult subjects following introduction of district heating. The same measurements have previously been made when wood burning was common, which makes it possible to evaluate changes in exposure levels resulting from such a transformation of heating systems (Loh *et al* 2001). In a separate project, a method for personal diffusive sampling of butadiene in the general population will be further developed and thoroughly validated (“Personal butadiene”).

Several activities in the *Program* relate to exposure and these will be coordinated actively. However, there are also numerous other national and international activities with a focus on exposure to air pollutants which will be taken into account in the health risk assessments and integrated in the final synthesis report.

Quantitative relation between health effects and exposure to airborne particles and pollution mixtures

The short-term association between air pollution and mortality is well established. The mechanisms are however still unclear and there is a great need of studies specifically addressing mechanistic aspects of this relation. The epidemiologic air pollution research by program participants so far has largely been focused on effects of long-term exposure, including lung cancer and asthma in children (Pershagen *et al* 1995, Nyberg *et al* 2000, Gustavsson *et al* 2000). To some extent, acute effects of air pollution in asthmatic patients have also been studied (Svartengren *et al* 2000). Thus, the *Program* will include several short-term effect studies, specifically designed to give important information also at low levels of pollutants.

Because short-term studies are unsuitable for quantitative environmental risk assessment of mortality, much attention has been given to the only three studies published so far on the long-term effects of air pollution on mortality (Dockery *et al* 1993, Pope *et al* 1995, Abbey *et al* 1999). The latter type of study is potentially more informative for risk assessment, but has its shortcomings. It is very sensitive to confounding and it involves characterization of long-term exposure for the whole study population. Ideally, all information of importance for

mortality should be collected for each individual, which makes such studies extremely costly. It was recently shown that meaningful individual information on historical exposure can be generated in a cost-efficient way (Bellander *et al* 2001b). These methods will be further developed as previously indicated, and applied to existing and future cohort and case-control set materials.

In the *Program*, an existing case-control study on myocardial infarction in Stockholm will be used to study the relation between long-term exposure to ambient air pollution and the risk for myocardial infarction (“LEAP”). The methodology is similar to the one already used in a study which implicated ambient air pollution from motor vehicles as a cause of lung cancer in Stockholm (Nyberg *et al* 2000). In principle, long-term exposure to air pollution will be assessed using retrospective emission databases and annual dispersion models for different air pollutants, which will be linked to the individual address coordinate for each subject for the corresponding year using GIS. Thus, yearly exposure to NO_x, NO₂, CO, and SO₂ during more than 30 years will be assessed for each study subject. In essence, the study design makes it feasible to separate traffic-related NO₂ emissions from that generated by other sources, and NO₂ will be used as a tracer for the diverse mixture of air pollution generated by road traffic.

A basic epidemiologic design is the cohort study, and the main reason why such studies are not performed is –as mentioned above– the high costs involved, primarily to generate detailed exposure information for each study subject. In the *Program*, we will study the feasibility of setting up a large cohort study in collaboration with other centers in the Nordic countries (“Cohort feasibility”). The potential environmental exposure contrasts that may be captured at reasonable costs will be explored, as well as the added value of clinical examinations of the cohort members. This feasibility study will result in an assessment of the practical and economical possibilities to construct a new cohort to investigate the health effects of air pollution, or possibly the use of already existing cohorts for this purpose. For example, the retrospective dispersion models already described may greatly facilitate exposure assessment in such a cohort.

Other studies will assess the relation between ambient air pollution, primarily from motor vehicles, and development of asthma in children (“AIRALLERG”). These studies are performed in collaboration with several European centers, and with financial support from the European Union. In another study focusing on airway effects from air pollution, GIS will be used to evaluate associations between exposure and effects using health statistics (“GIS-tool for exposure”).

The above mentioned manifestations of ill-health are not the only important from a public health perspective. Other – more “soft” – expressions of risk also need to be quantified, focussing on the quality of life. There is a great need for estimates of the effect of air pollution on “quality-adjusted life years”, “disability-adjusted life years”, “restricted activity days”, and similar indices. Investigations with such aims will be welcomed to apply for funding from the free funding part of *Program*.

Variability in sensitivity within the general population for health effects related to exposure to air pollution

Although an association between short-term variations in air pollution levels and short-term variations in health outcomes is seen in most studies of this kind, it is still uncertain which are the mechanisms and which are the sensitive subgroups in the population. It has been postulated that old people with a history of previous serious health problems are mainly

affected, but very little information is available. In the *Program*, we plan to study hospitalization and death in relation to variations in air pollution for subgroups with and without previous hospitalization for myocardial infarction and other “cardiopulmonary” diseases (“HEAPSS”, “SENSI”). These studies will in part be performed in collaboration with other groups in Sweden and Europe, with simultaneous characterization of ultrafine particles in all centers.

Previous data have shown that exposure during 30 min to air pollutants in a road tunnel, or to NO₂ in controlled experiments, enhances the airway response to pollen in mild asthmatics (Strand *et al* 1997, Svartengren *et al* 2000). Ongoing studies show that the increased responsiveness is associated with inflammatory changes. In the *Program*, the road tunnel setting will be used to further study these changes in samples using bronchioalveolar lavage, and induced sputum and blood (“SALUT II”).

Cardiac arrhythmia has been suggested to be responsible for part of the short-term effects of air pollution on mortality (Peters *et al* 2000). Animal and human studies have shown that particulate air pollutants may alter the cardiac function, influencing both the average heart rate and the rate variability (Watkinson *et al* 1998, Pope *et al* 1999). In the *Program*, we will study the role of air pollution in the onset of life-threatening ventricular arrhythmia in patients with internal cardiac defibrillators, which automatically keep records of events of arrhythmia and defibrillation (“ALVA”). This study will be performed in collaboration with cardiologists in Stockholm, Göteborg, and Malmö. In the tunnel exposure setting mentioned above, we will study the effect of short exposure to high levels of traffic air pollution on heart rate variability in healthy volunteers (“SALUT II”). Another group that may be highly susceptible to air pollution are persons with chronic bronchitis. A panel of such patients will also be investigated in the tunnel setting, monitoring lung and heart functions.

Contribution to science

Most of the projects described in this proposal are not only important for the development and implementation of prevention, they are also of high international scientific standard. We expect several results to have considerable international interest, which is favorable for Sweden in international regulatory efforts, as well as in future applications for international grants and collaborations. In addition, the *Program* will greatly contribute to the building of research capacity in Sweden within this field, and strengthen inter-disciplinary and inter-institutional collaboration. Particular contribution to the international air pollution research will be the analysis of health effects from air pollution at moderate levels of exposure as found in our country. Other topics will also bring special attention to the scientific community, e.g. the use of GIS in combination with retrospective dispersion models, the development of emission databases for particulate matter, the planning of a new cohort study, and the road tunnel as an experimental exposure setting. The development and experiences of an integrated inter-disciplinary national air pollution and health effects program will also be closely followed by other researchers. Some of them will also be directly affected by such a program, through international and national collaboration with partners in specific projects included in the *Program* or by funding of own projects from the free funding part.

Collaboration and relation to similar national and international activities

It should be recognised that the start of this *Program* will result in new and extensive contacts between experts within the field who can collaborate in the separate projects and contribute to the synthesis of health risk assessments. The frequent communication with national and international professionals will provide a knowledge base that goes beyond the experiences

made in the single projects in the *Program*. Thus, not only data from the studies within the *Program* will provide support for decisions and policy making, but also the access to a continuously growing international knowledge base on air pollution and health.

Some of the projects or parts of the studies included in the *Program* focuses on similar exposures or study subjects, and will thus be performed in cooperation with each other. The three projects including measurements of personal exposure, and indoor/outdoor levels in residential areas (i.e. “Wood smoke exposure”, “Personal PM_{2.5} exposure”, and “Indoor/outdoor levels”) will be performed in close collaboration between the partners, with joint use of equipment and regular exchange of ideas and results. The study of personal PM_{2.5} exposure will also benefit from experiences in other wood smoke projects by the same research group, funded from another research program run by the Swedish National Energy Administration (Emissions and air pollution from combustion of biofuels). This parallel research program has a similar aim as the proposed *Program*, but focuses on the development of tools for physical planning and emissions of pollutants from fuels for electricity and heat supply, especially biofuels. To further integrate the efforts in these two programs, a joint seminar will be planned in the first period of the *Program*. Moreover, close collaboration is also intended between the groups at Lund and Göteborg Universities, planning to compare personally measured levels of fine particles with deposition in airways (a project not listed in the present application). Another area that will benefit from the integration within the program is the modeling of population exposure (i.e. “PASTA”, “GIS-tool for exposure”, and “Software tool exposure”). The groups that are planning such studies will meet to exchange protocols and experiences. The Swedish Meteorological and Hydrological Institute (SMHI) will also be invited. The establishment of working groups responsible for different issues (e.g. exposure, GIS, epidemiology) that is described below, and will increase interaction and exchange of knowledge between research groups in the *Program*.

International collaboration is also important in the *Program*. Both national and international partnerships have already been mentioned for some of the projects in this application, e.g. “HEAPSS”, “AIRALLERG”, and “ALVA”. The development and validation of dispersion modeling will be performed in collaboration with the Utrecht University in the Netherlands, as well as with the GSF Institute of Epidemiology in Munich. The results will be important for correct assessment of the average population exposure to ambient air pollutants, and also for the identification of heavily exposed groups. A partner for detailed characterization of personal exposure to wood-smoke is Tord Kjellström, Department of Community Health, The University of Auckland, New Zealand. A unique study of health effects of high levels of wood-smoke in New Zealand will be invited to apply for funding in the free funding part, including a better characterization of exposure, to assess exposure-response relations (not included in the present application). In the *Program*, we intend to implement an air quality management system in Scania, in collaboration with our Danish neighbors. It will serve multiple purposes, e.g. for research on risks with air pollution and for risk assessment. It will also be applicable in an alert system for warning the population for upcoming high pollution levels (“GIS tool for exposure”).

Scientific knowledge and research capacity gained from the *Program* is also important for Sweden’s participation in different international forum, such as the negotiations within the European Union. Thus, international ongoing activities in the air pollution field especially in Europe, e.g. the 6th framework program for research and development, CAFE (Clean Air for Europe), which is an initiative from DG Environment within the European Union to support air pollution control strategies and legislation in Europe, as well as other research programs

related to air pollution will be closely followed. A direct link between the *Program* and CAFE is secured by the representatives from the Swedish EPA who are actively involved in both programs. Other international organizations important for the *Program* include the European Environment Agency (EEA), United Nations (UN), and World Health Organization (WHO). In Sweden, especially the Swedish EPA, the Swedish Energy Administration (STEM), and the Swedish National Road Administration (SNRA) are involved in these issues. People active within the Swedish ASTA program (International and National Abatement Strategies on transboundary air pollution) will also be invited to interact with the *Program*. ASTA has similar goals as the *Program*, e.g. to produce air pollution research important for international abatement strategies, to ensure Swedish competence for international negotiations, and to increase understanding of air pollution science and policy. In addition, many private companies (e.g. automobile, oil, energy-production) and non-governmental organizations (NGOs) will be involved in the discussions related to the *Program*. An illustration of the relation to similar national and international activities and organizations is given in the figure below. In essence, this figure provides a picture of the added value of the *Program* for other similar actions and illustrates how the results may influence the most important target groups for the *Program*. It also highlights some channels for direct input into the *Program* and interaction with others in the air pollution field. However, it does not provide a complete description of the interaction between the *Program* and all other parties active in this field, but serves merely as an example of the possible future role for this program.

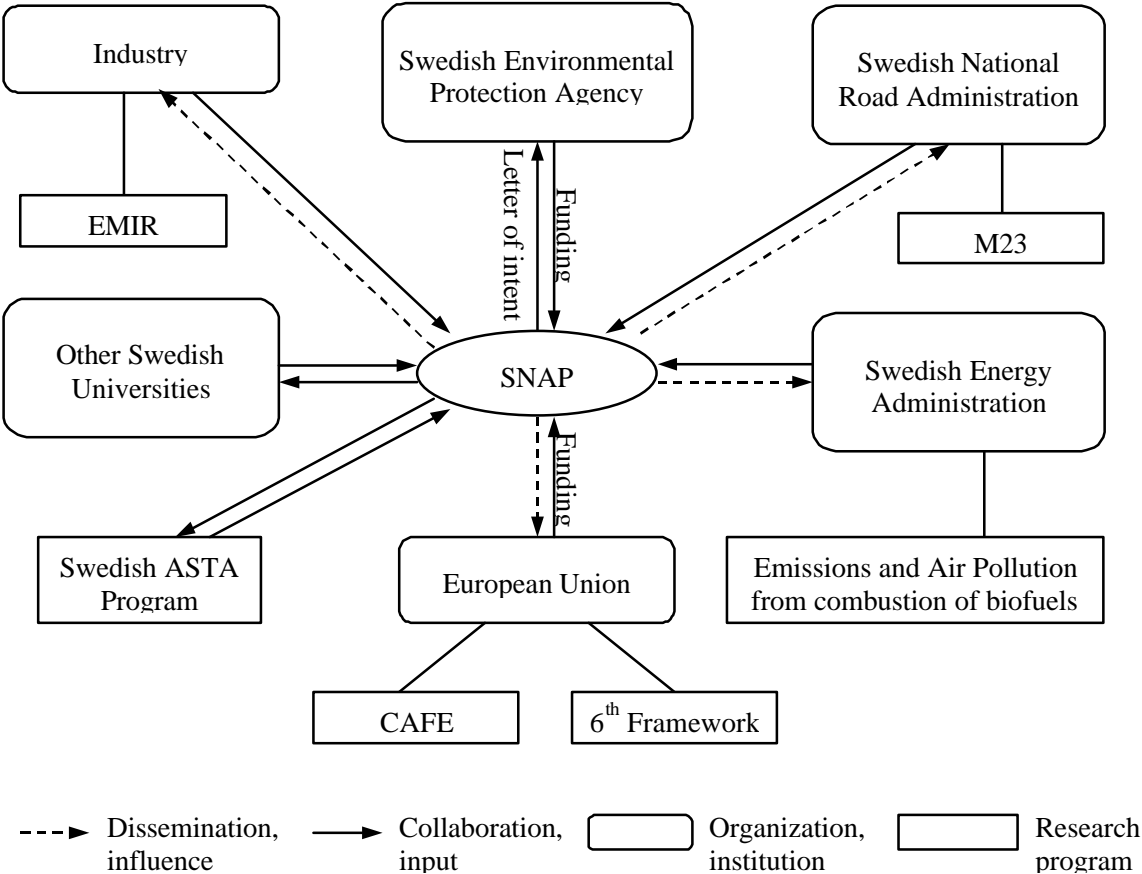


Figure 1. An example of the added value of the *Program* in relation to similar national and international activities and organizations.

Free funding part

In order to further strengthen the collaboration in the *Program* and to give the opportunity for other groups to receive funding, it is useful to keep a part of the *Program* open and reserve some of the funding for this purpose. There will be two calls for external projects to be funded by the free funding part, one in 2002 and another during 2003/2004. As previously mentioned, important aspects that are not covered in the *Program* will also be called for among other research groups. Groups that will receive such funding and other groups with independent funding may eventually be integrated into the *Program*. Of high relevance for the research topic described in this application are some of the projects proposed by the groups behind the Järholm and Vainio letters of intent to the Swedish EPA for national research programs.

The application by Järholm from Umeå University is focused on particles and covers exposure characterization, epidemiological studies and experimental studies. Some of the exposure studies in that application are already integrated in this program through a mutual partner. Bertil Forsberg has carried out extensive research at Umeå University related to air pollution and health, and he is involved in the “SENSI” and “PASTA” projects, as well as in other ongoing studies funded by e.g. the Swedish Energy Administration and the EU, including outpatient visits and diary studies. The experimental studies in the Järholm application concern acute effects from wood smoke particles, and would also add to the *Program*. The Vainio proposal concern studies of high-risk populations and methods for risk quantification. It is anticipated that several research activities planned within the framework of that program may be pertinent to the *Program*.

The mechanistically oriented experimental studies from the group led by Gunnar Bylin should also apply within the free funding part. A study that the *Program* suggests to be planned is that of reproductive effects and perinatal mortality. Another topic not covered in the *Program* and thus suitable for applying to the free funding part is studies of risk in terms of quality of life, e.g. “quality-adjusted life-years” or “disability-adjusted life-years”. Aggravation of symptoms, e.g. asthma, is efficiently studied in panel studies. Such studies may provide information on loss of quality of life due to air pollution. Gene-environment interaction may provide further knowledge on mechanisms for increased health risks from air pollution, which would be important for risk assessment, cost-benefit analysis, and future regulation.

In summary, the following topics will be given priority when allocating funding from the free funding part of the *Program*:

- Gene-environment interaction.
- Mechanisms of effects of air pollution.
- Effects of exposure to air pollution during pregnancy and infancy.
- Wood smoke: exposure and health effects.
- Loss of quality of life due to air pollution.
- Environmental exposure to benzene and other carcinogens: methods for assessment of exposure and health effects.

Dissemination of results

The results will be disseminated to international, national, regional, and local authorities, as well as to national stake holders and to the international scientific community. The individual studies will be presented at national and international scientific conferences, published in scientific journals, and in Swedish language publications directed to authorities and the general public. As knowledge accumulates in the *Program*, comprehensive presentations will be organized in the form of work-shops and seminars focussed on specific topics, as well as

an international symposium on advances in risk assessment. Such a meeting on health effects of air pollution was jointly organized by the Institute of Environmental Medicine and the Royal Academy of Sciences last year. Authorities and industry participated in the discussion of the latest international and national findings, together with the leading scientists in the world in this field. Public work-shops are planned for 2002, 2003, 2004, and 2005, while the international symposium most likely fits best towards the end of the *Program*, i.e. in 2006.

Plan for information and interaction

Great attention will be focused on the strategies and target groups for dissemination of results. To accomplish the aim of production, dissemination, and communication of valid and high quality data on air pollution and health, it is pertinent that those directly involved in the *Program* are aware of its aims, structure, presumed results, and everyone's responsibilities. Thus, the *Program* will start off with a meeting in November 2001, focusing on strategies for this "internal" communication, and the plans for future information activities. During this meeting, the applicants and co-applicants, as well as the representatives from the Swedish EPA involved in the program board, will discuss the issues of commitments according to the contracts for funding and towards the *Program*, the involvement in recurring dissemination tasks, regular support and maintenance of the *Program*, and potential problems that may occur underway. The specific aim for this meeting is to assure that those involved are aware of the aims, strategies, and routines of this process. Likewise, it is important that the target groups are well defined and that they are aware of the purpose of the *Program*, and have the knowledge of how to use the results. This "external" communication will be assured mainly by the public workshops that will be performed on a yearly basis, as mentioned above. Invitations will be sent to representatives from the primary target groups, e.g. the Swedish EPA, the Swedish National Road Administration, the Swedish Energy Administration, the Swedish ASTA program, and industry (e.g. car producers). The secondary target groups, mainly the general public, politicians, and mass media, will be reached directly through specially organized events such as pre-organized press conferences concerning new data from the projects in the *Program*, or indirect via information from e.g. national, regional, or local authorities, or others of the primary target group.

Channels for broad information regarding results from certain projects include radio, television, newspapers, and scientific literature. New data originating from projects in the *Program* will also be published in upcoming regional and national environment and health reviews, such as the recently published National Environmental Health Report 2001, which will be updated regularly (Socialstyrelsen 2001). At the middle of the program time, i.e. mid-2004, an English mid-term report will be produced, identifying any proposed change to the *Program* or budgetary allocation. Finally, a Swedish synthesis report will be planned to the end of the *Program*, evaluating the state of the art in air pollution and health. A website will also be produced at the start of the *Program*, containing general information about the *Program* and its individual studies, as well as detailed information on how to contact those involved and how to apply for funding from the free funding part. This channel may also become useful as a forum between the *Program* and the general public.

It is essential that tangible information strategies can be assessed to allow follow-up of such activities and to provide data that can be evaluated. For instance, participation in the seminars and workshops organized by the *Program* or "search hits" on the program's website is easily measurable, while the use of data or statistics from the *Program* in practical public health work may be more difficult to assess. However, it should be possible to evaluate to what extent knowledge gained in the *Program* has been used in guideline setting or criteria

documents. The potential for follow-up of the results and evaluation of information activities from the *Program*, will be specifically discussed at the first meeting in the program group in November 2001.

Interaction between the *Program* and other parties is essential for its gradual development and future success. This is promoted to some extent through the free funding part. However, additional efforts will be made to extend the information activities into an “interaction plan”. These efforts include jointly organized meetings with other groups, particularly those at Umeå University. The program group should be kept flexible during the program period, according to representation in the free funding part. Negotiations to arrange a seminar together with the research program on biofuels, funded by the Swedish Energy Administration, will be started in November 2001. These two programs have somewhat similar activities regarding exposure assessment, which makes it suitable to arrange such a joint seminar early in the *Program*, i.e. during 2002. The *Program* will particularly interact with the newly built Network for particle emissions and related gases from transportation and energy production, hosted by prof. HC Hansson at the Institute of Applied Environmental Research (ITM), and jointly funded by the Swedish EPA, the Swedish National Road Administration, and the Swedish Energy Administration. The aim of the Network is to support research and efficient exchange of knowledge between scientists, industry and others, concerning particulate air pollution from the energy and transport sectors. A close coordination of information activities between the *Program* and the Network will improve both efficiency and impact of dissemination. The *Program* has already been invited to participate in the Network’s upcoming seminar in spring 2002, and information will also be shared on the Network’s website.

Time table

The present program is planned for a period of five years. In the first part of the period the emphasis will be on models for exposure assessment and quantitative relationships. In the second part of the period the emphasis will be on sensitive subgroups and risk assessment. Table 2 below illustrates the time schedule for the individual project in relation to each other and to the time frame of the *Program*.

Table 3. An overview of the time schedule for each single project included in the *Program*.

No.	Project title	2001	2002	2003	2004	2005	2006	
1.	“AIRALLERG”	Project work					xxx	xxx
2.	“PASTA”	Project work					xxx	
3.	“Wood smoke exposure”	Project work				xxx		
4.	“Personal butadiene exposure”	Project work					xxx	
5.	“Personal PM _{2,5} exposure”	Project work					xxx	
6.	“Indoor/outdoor levels”		Project work					xxx
7.	“LEAP”		Project work		xxx			
8.	“Cohort feasibility”		Project work			xxx		
9.	“SENSI”		Project work				xxx	
10.	“HEAPSS”		Project work			xxx		
11.	“ALVA”		Project work					xxx
12.	“SALUT II”		Project work					xxx
13.	“GIS-tool for exposure”		Project work				xxx	
14.	“Software tool for exposure”		Project work					xxx

All planned research activities within the *Program* will be reported before the end of the *Program* period. About 10 PhD students will be partially funded through the *Program*. Before the end of 2001 each project leader will report on the planned time-table for each student. Our goal is that most students will be examined within the program period.

Phasing out

Because of the structure of the *Program* in several smaller projects, we anticipate no major problems with phasing out. All activities described in the *Program* will have been concluded by the end of 2005, and disseminated before the end of the *Program* in 2006-09-30.

Undoubtedly, the findings in the planned studies will also generate new research questions of which some will be addressed within the free funding part of the *Program* and others may be further investigated in future projects after the *Program* has ended.

Development of program, consultations

The planning of the *Program* has been performed by the applicants and co-applicants, in collaboration with representatives for the Swedish EPA as well as representatives of industry and other groups of researchers. The proposal was written by Mats Rosenlund at the Department of Environmental Health, Stockholm County Council, together with the program's chair and co-chair, and with input from members of the program group. The background, aims, and content of the *Program* was presented for discussion at a seminar in Stockholm the 28 March 2001, in which 39 persons from the program group, national authorities, and the major target groups participated. Important input from the attendants of this meeting has also been included in the present program application.

Organizational structure of the program

The program management will be organized in Program Directorate, Program Board, and Working Groups (figure 2). The program directorate is constituted by the applicants and led by the program director. It will be responsible for the continuous coordination, including consultations on project contracts. The proposed research will be performed mainly by the applicants and the co-applicants, but also by other groups. The principle investigators of each single project and those who were actively involved in the planning of the *Program*, form the Program Board. The main stakeholders and others will be invited to participate in this board, which will allow the Program Board to have the function of a steering group. There will be representatives of the Swedish EPA and other authorities, as well as representatives of industry, in particular from the transport and energy sectors, and the municipalities. The Program Board will plan the program activities including recurrent dissemination of the results, and is responsible for mid-term and final reporting of results, and phasing out of the *Program*. In addition, the board will develop criteria for requirements on project contracts. The Program Board will meet twice yearly to keep all interested parties updated on the progress of the *Program* and deal with matters of principal interest, such as valuation of the relevance of applications for free funding, the integration of new groups into the *Program*, and reporting to the Environmental Research Board.

Special working groups will be set up to deal with similar topics across the single project groups. Topics that initially form the bases for such groups include exposure, GIS, and epidemiology. The working group on exposure will be situated in Göteborg, under the leadership of Dr Gerd Sällsten. The working group on GIS will be lead by Dr Hans Welinder in Lund, and the working group on epidemiology will be located in Stockholm and managed by Dr Tom Bellander. These groups will meet twice a year, to foster contacts and collaboration further. They should serve as expert councils in relation to national and regional

authorities, and a link between the municipalities and experts. Their task should also include production of synthesis reports and presentation of new scientific results within their specific field. However, it must be stressed that the *Program* is not intended to produce new criteria documents for single pollutants, but to increase the general knowledge and basis for health risk assessment related to air pollution. The ambition is that these working groups will survive and be active as a forum for discussion also after the end of the *Program* period. The figure below describes the organizational structure of the *Program*.

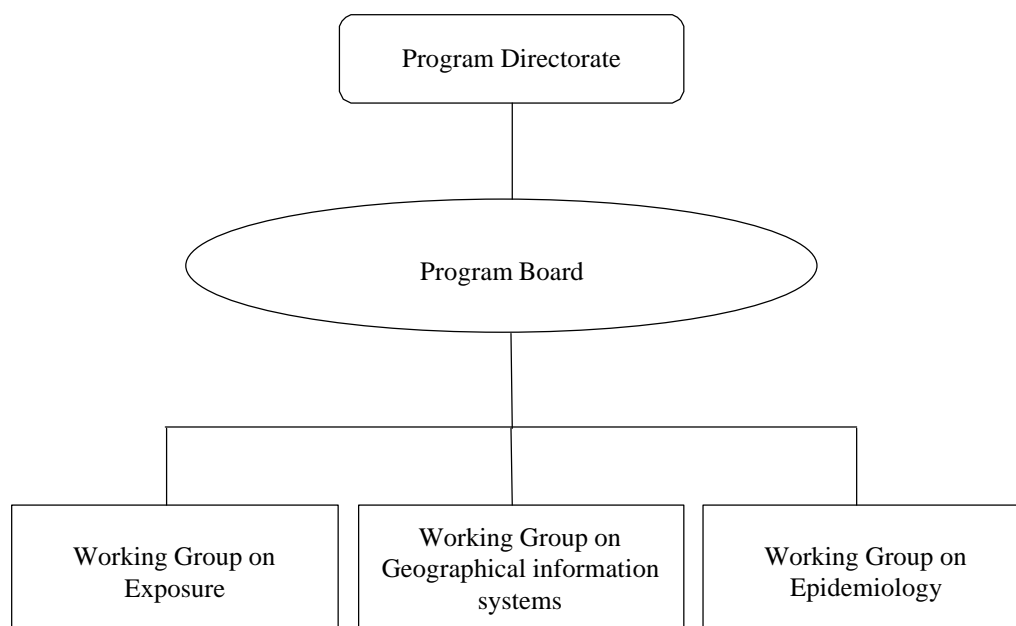


Figure 2. Organizational structure of the *Program*.

Budget

The total cost of the *Program* would amount to about 33.9 MSEK for the whole 5-year period, distributed in the major activities indicated in Table 3 below. The yearly meetings, as previously pointed out, provide regularly updated input to the *Program* and serve as a forum for discussion between applicants, co-applicants, reference group, and other interested parties. In addition, three public workshops and one international symposium will be held within this program budget. Administration and co-ordination of the *Program* includes 10% director, 20% vice director, and 30% scientific secretary (the Program Directorate) for 2001-2005 and with 50 % increase of this time for 2006. It also includes funding for the program group and work-group meetings. The budget for dissemination activities comprises yearly public workshops, and 1 symposium.

Table 4. Budget for major activities in the *Program* during each year.

Activity	2001*	2002	2003	2004	2005	2006 [†]	Total
Projects	1462	3698	4523	2715	1416	0	13814
Management and administration	400	1000	1000	1000	1000	1200	5600
Dissemination, information	0	200	200	200	400	400	1400
Free funding part	0	2500	2500	3500	3400	1200	13100
* 3 months only	<i>Total:</i>	1862	7398	8223	7415	6216	33914
[†] 9 months only							

Some of the projects included in the *Program* also have financial support elsewhere, and it is possible that funding may be applied for also from other sources. The current and proposed

financial sources include the Swedish Environmental Protection Agency, the National Road Administration, the Swedish Transport and Communications Research Board, the Swedish Council for Work Life Research, the Heart-Lung Foundation, the Swedish National Energy Administration, the Swedish Cancer Society, the Swedish Council for Health Care Sciences and Allergy Research, the European Union and the US Health Effects Institute. The total cost for each project, the requested amount from the *Program*, and specification of other grants are shown in Table 4 below.

Table 5. Total cost, other funding, and requested amount from the *Program* for each project.

No. Project title	Total cost (TKr)	Other funding		Request (TKr)					
		(TKr)	Source*	Total	2001	2002	2003	2004	2005/6
1. "AIRALLERG"	2999	2999	EU	0	0	0	0	0	0
2. "PASTA"	3968	1868	KFB, SEPA	2100	500	700	550	350	0
3. "Wood smoke exposure"	996	0	–	996	271	472	253	0	0
4. "Personal butadiene"	1282	0	–	1282	207	397	458	220	0
5. "Personal PM _{2.5} exposure"	2796	0	(STEM)	1522	231	437	536	318	0
6. "Indoor/outdoor levels"	1895	0	–	1895	0	222	640	517	516
7. "LEAP"	1156	1156	SEPA	0	0	0	0	0	0
8. "Cohort feasibility"	297	0	–	297	0	150	147	0	0
9. "SENSI"	1330	1330	–	1330	0	0	500	330	500
10. "HEAPSS"	1596	1596	EU, SEPA	0	0	0	0	0	0
11. "ALVA"	1760	1320	SEPA	440	0	0	0	440	0
12. "SALUT II"	4548	0	(HEI)	2300	0	700	800	400	400
13. "GIS-tool for exposure"	1152	0	–	1152	253	470	429	0	0
14. "Software tool for exp."	880	0	(SEPA)	500	0	150	210	140	0
<i>Total</i>	<i>26655</i>	<i>10269</i>		<i>13814</i>	<i>1462</i>	<i>3698</i>	<i>4523</i>	<i>2715</i>	<i>1416</i>

* EU=European Union; KFB=the Swedish Transport and Communications Research Board; STEM=Swedish Energy Administration; SEPA=Swedish Environmental Protection Agency; ÖFS=Öresund Research Secretariat; CF=Swedish Cancer Society; FAS=Swedish Council for Working Life and Social Research; (in parenthesis)=intended future funding source.

The applicants' qualifications

Göran Pershagen, MD, PhD, is chairman of the Institute of Environmental Medicine and head of its Division of Environmental Epidemiology. He is author of more than 100 scientific publications in environmental health and risk assessment, with particular emphasis on outdoor and indoor air pollution. He has repeatedly served as consultant to international organizations, such as EC, IARC and WHO as well as to national authorities.

Tom Bellander holds a MSc in chemistry and a PhD in Med Sci, and is the author of more than 30 original papers. He has worked mainly with environmental and occupational epidemiology and heads the Division of Epidemiology at the Department of Environmental Health, Stockholm County Council.

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