NATIONAL INSTITUTE OF PUBLIC HEALTH AND ENVIRONMENTAL PROTECTION
BILTHOVEN

Report no 441520003

Health Impact Assessment Schiphol Airport

- Executive summary -

B. Staatsen, E. Franssen, E. Lebret

July 1994

Restricted mailing list

1 H.G.C.M. de Brouwer, Directie Geluid en Verkeer, VROM-DGM

2 B.C.J. Zoeteman, plv. Directeur-Generaal Milieubeheer

3 Directeur-Generaal van de Volksgezondheid

4 Depôt van nederlandse publikaties en nederlandse bibliografie

5 Directie RIVM

6 Hoofd Bureau Voorlichting en Public Relations

7 Bibliotheek RIVM (2x)

8 Bureau projecten- en rapportenregistratie

9-75 Reserve-exemplaren

Contents

1 Introduction

This report describes the public health impact of environmental pollution originating from activities around Schiphol national airport, the Netherlands. This investigation was part of an integral Environmental Impact Assessment (EIA) which was mandatory because of a future expansion of the airport. The National Institute of Public Health and Environmental Protection (RIVM) has been assigned by the Ministry of Housing, Physical Planning and Environment to prepare and coordinate a Health Impact Assessment. In December 1993, RIVM, in collaboration with other Dutch research-institutes has published a first report on this issue (in Dutch). A description of the current health status, an identification of existing gaps in knowledge, as well as proposals for future research and monitoring activities were made. The results of this study are presented in this executive summary.

Several separate approaches have been applied for this Health Impact Assessment. One was based on combining (estimated) pollutant exposure levels in the Schiphol study area with exposure-response relations derived from the literature ('risk evaluation'). The second approach consisted of a geographical study on a small area scale using hospital admission rates for several cardiovascular and respiratory diseases. Thirdly, a survey on risk perception and annoyance has been conducted in a sample of the population in the Schiphol area and the general Dutch population. In addition a subgroup of the Schiphol population was interviewed.

Experts from several countries showed interest in the study. This executive summary was written to inform those who are interested. For more information please contact:

E. Lebret, B. Staatsen or E. Franssen
Department of Chronic Disease and Environmental Epidemiology
National Institute of Public Health and Environmental Protection
P.O. Box 1, 3720 BA Bilthoven, the Netherlands.
E-mail: Lebret_e@RIVM.NL, Staats_b@RIVM.NL, Franss_e@RIVM.NL
Phone: 31-30-743804

2 Background and methods

The terms of reference for the Environmental Impact Assessment (EIA) were based on, amongst others, an advisory report of the State Inspectorate of Public Health. These terms require a description of the current health status and risk perception of residents living around Schiphol airport. Also proposals are required for future research on possible health effects in relation to airport activities of which there is an apparent lack of knowledge currently.
Prognoses of health effects of different airport expansion scenarios were considered infeasible, given the limited knowledge available. As specified in the terms of reference, a proposal for a system to monitor the health status of the population around Schiphol airport in the case of airport expansion was made instead.

To obtain an impression of the health effects that can be expected in the first place, a risk evaluation was performed by evaluating current pollution levels and the available body of science on health effects from airport related pollutants. For a risk evaluation procedure evidence for a causal relationship as well as knowledge of a quantitative relationship between the amount of exposure and specific health effects are needed (exposure-response relationship). For each separate pollutant it has been determined whether it can affect health.
Health in this context was defined as a status of general physical, mental and social well-being and not merely a long lifetime or the absence of a disease or infirmity. The extent to which normal social performance is possible was also of major concern. Annoyance caused by noise or odour and fear for health impairment ('risk perception') can affect the mental and social well-being and normal performance and were therefore considered as health effects. One has to remember, however, that the health status is determined by an interaction of several genetic and environmental factors of which environmental pollution is only one.

The pollutant-oriented risk evaluation procedure was performed for the following pollutants related to airport activities: noise, air pollution, (kerosine) odour and radiofrequent radiation around radars. The literature on risk perception with respect to air traffic was also reviewed. Except for noise, however, there were only a few studies available which are relevant for the situation studied.
If possible, an exposure-response relationship was derived. These exposure-response relationships were used to estimate the extent of effects expected among the population at a certain exposure level. To assess the number of people exposed, demographic data for the EIA study area (55 x 55 kilometre around Schiphol airport) for 1991 and 1992 were used. Around 2 million people live in the study area. Figure 2.1 shows the location of the airport and the study area. The population density is shown in figure 2.2.
A Geographic Information System was used to combine population data and locations of dwellings with the output of noise and air pollution models to provide detailed estimates of population exposure.

Figure 2.1: Location of Schiphol airport and study area (shaded area).

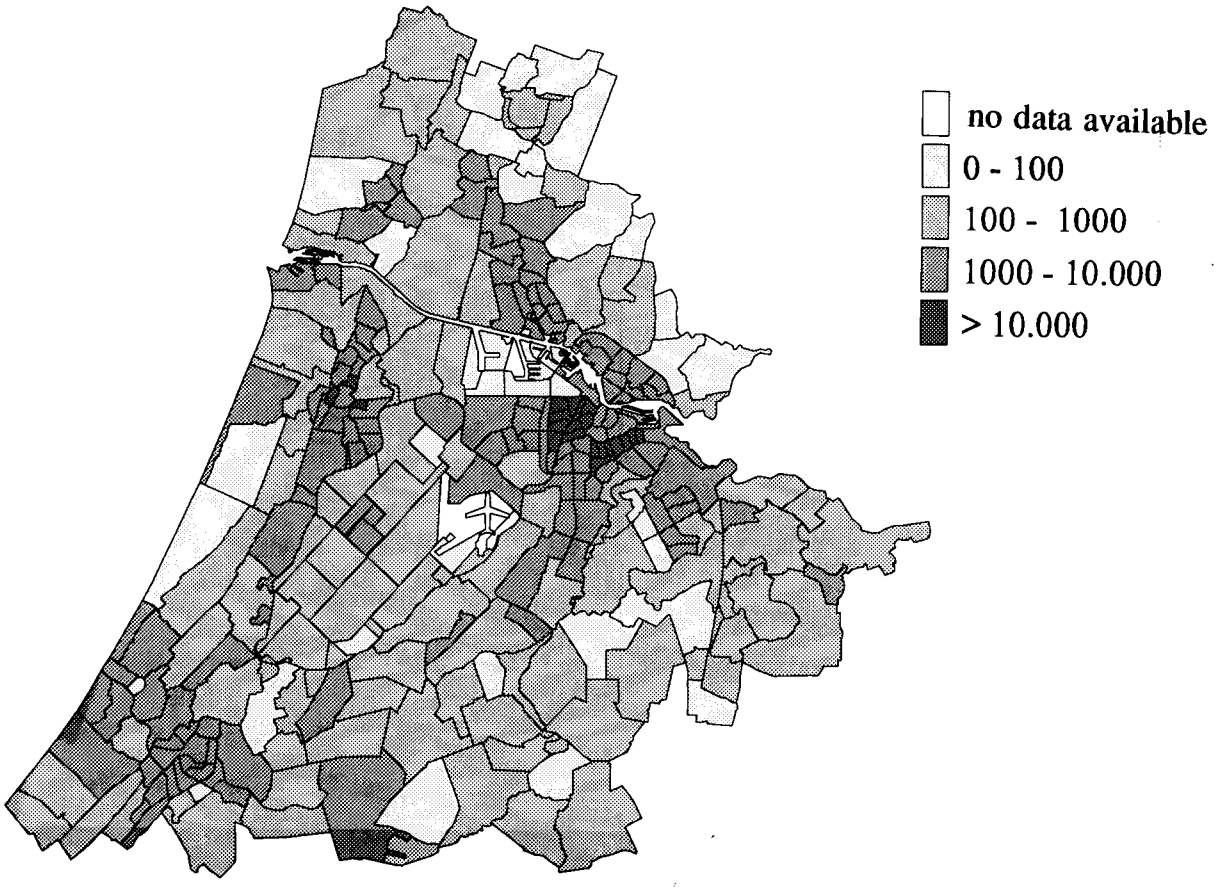

Figure 2.2: Population density per postal code area in the Schiphol study area (1992)

The results of the risk evaluation are estimations and may differ from the actual health status of the population living in the vicinity of Schiphol airport for several reasons. Firstly, this may be due to uncertainty in the exposure data and exposure-response relations. Secondly, other health determinants like life style or genetic susceptibility, were not considered in the risk evaluation. Thirdly, most health effects reported in the literature were carried out at high exposure levels, often under experimental laboratory conditions. The extrapolation of effects to low exposure levels, i.e. levels to which the general population is exposed, therefore has a large margin of uncertainty. Finally, the fact that people are not only exposed to aviation related pollution, but also to other types and sources of pollution was not taken into account. Moreover, knowledge of pollution associated with aviation is still very incomplete.

The risk evaluation procedure was considered insufficient to assess the actual health status because of the reasons mentioned before. An evaluation of the current health status, including the risk perception of the population living in the vicinity of Schiphol Airport was therefore carried out also.
The current health status was evaluated in a geographical study using hospital admission rates. Currently available health record databases were used for this geographical study, because the EIA guidelines and time frame precluded gathering of new data on the health status. It was investigated whether differences in the incidence of diseases, expressed in hospitalization rates, occur in the EIA study area that can be linked to the presence of Schiphol airport.

A second question is to what extent the population in the Schiphol area is annoyed or afraid of acute or chronic health impairment caused by calamities or pollution related to the airport. Complaints about noise and odour in the Schiphol area registered by the Environment Advisory Committee Schiphol and the province of North Holland were studied. In addition, a brief survey on annoyance and risk perception was conducted.

3 Results of the risk evaluation: literature review

Table 3.1 summarizes the results of the pollution-oriented risk evaluation, based on the scientific literature. These results will be elucidated in this chapter.

Table 3.1 Estimated risks of environmental pollution related to Schiphol

Environmental agent	Estimated risks
Noise	* 100 000 people extremely annoyed * 1 500 extra cases of hypertension in a population of 1 600 000 people * increased number of people with sleep disturbance, concentration disorders, medicine use
Air pollution *NO_2, CO, Benzene, SO_2, black smoke, PAH*	* concentrations do not exceed limits * no increase of people with respiratory symptoms * no increase of cancer risk
Odour	* 108 000 people exposed to odour concentrations that exceed the odour limit * 36 000 people annoyed
Radiofrequent radiation (radars)	* no health effects

3.1 Noise

Aircraft noise exposure in the Netherlands is commonly expressed in Kosten-units (Ke). This measure was developed in the Netherlands by Kosten in 1963. The Kosten unit is defined by the maximum noise levels ($L_{A,max}$) during overflights, the total number of overflights, and the moments at which these overflights take place, averaged over a year. Overflights in evening and night time have more weight in the calculations than those during the day. Only overflights with a maximum noise level of 65 dB(A) are included in the calculations.
The Kosten unit is constructed to predict annoyance. Therefore, it is less appropriate to predict health effects other than annoyance and effects of short-term exposure.

Only noise levels in Ke were available as an indication of exposure to aircraft noise in the residential environment of Schiphol airport. Most exposure-response relations however, are based on other noise measures than the Kosten unit (e.g. L_{Aeq}). Conversion of noise measures to Ke is only possible to a limited degree. Figure 3.1 illustrates the noise levels around Schiphol airport. Table 3.2 shows the number of people per 5 Ke-class.

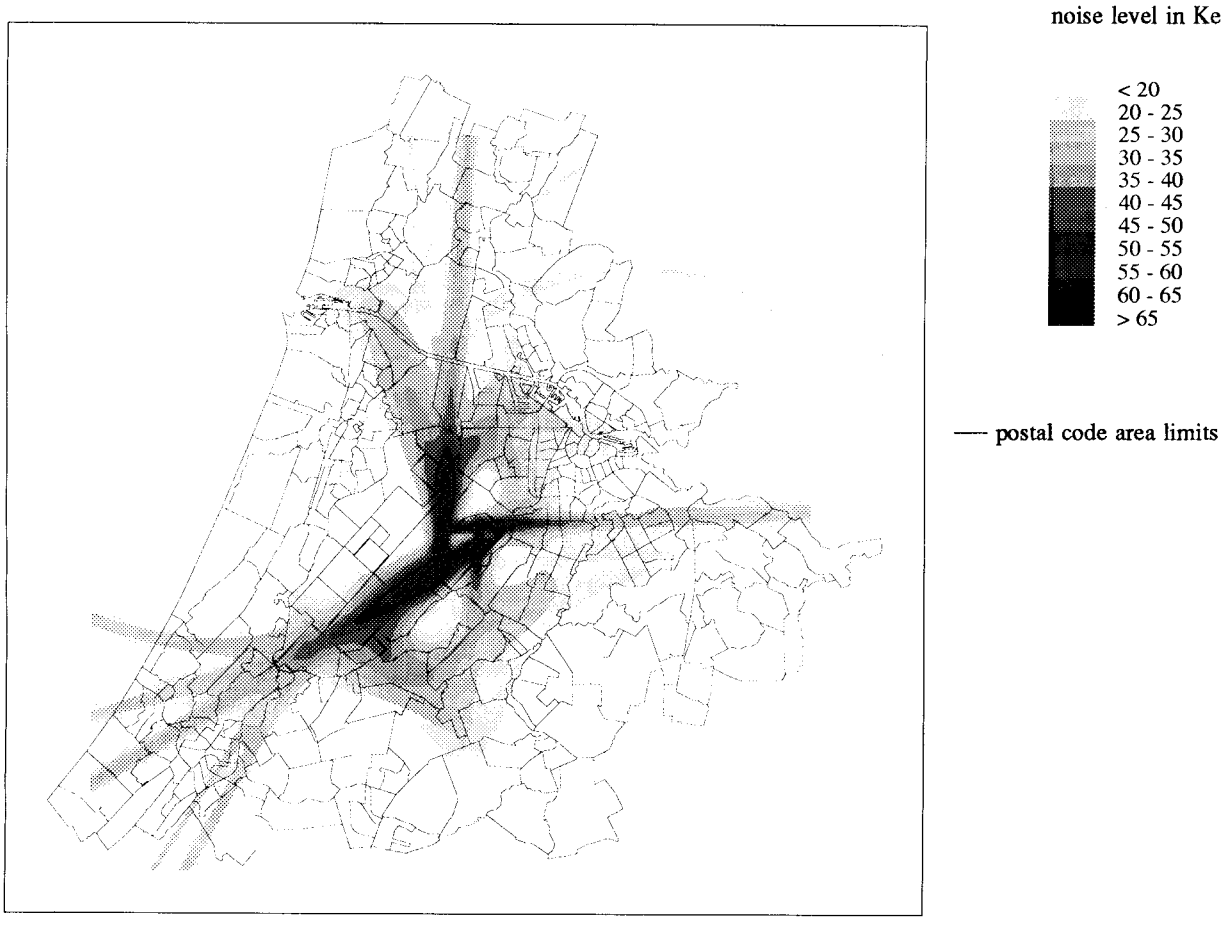

Figure 3.1 *Noise level around Schiphol airport in 1991 (Source: National Aerospace Laboratory) Note: some areas are aggregated and comparable with census districts*

Table 3.2 The number of people per 5 Ke-class

Ke-class	Number of people in the study area (all ages)
< 20	1 199 435
20-24	521 379
25-29	270 719
30-34	92 914
35-39	20 200
40-44	9 111
45-49	4 780
50-54	418
55-59	409
60-64	95
> 65	122
total	2 119 582

Alleged health effects from exposure to aircraft noise which have been studied include annoyance, sleep disturbance, hypertension, myocardial infarction, performance, low birth weight, mental problems, increased use of medication, hearing loss and impact on the immune system.

Based on the noise estimates in Ke, causal inferences and exposure-response relations derived from the literature, it is concluded that annoyance is the most important noise-related effect that will occur among the residents living in the vicinity of the airport. The number of people annoyed was estimated using an exposure-response relation derived from a community annoyance study around Schiphol Airport in 1980. When the presence of noise insulated houses is not taken into account, the estimated number of highly annoyed people older than 20 years, living in the area with a noise level of about 20 Ke, averages about 100 000 (table 3.1). In areas where noise levels are higher than 35 Ke, about 10 000 people are highly annoyed. If about 50% and 80% of the houses have double glazing, the number of highly annoyed people above a 35 Ke noise level will average 8 000 and 6 000, respectively. Using a more recently derived exposure-effect relation based on a compilation of several noise studies, the estimated number of extremely annoyed people in the whole study area is 75 000.

There are indications for an increased risk of hypertension and myocardial infarction when the equivalent sound level is more than 65-70 dB(A). This conclusion is based, however, on cross-sectional studies, prospective studies are not available yet. Based on a relationship between aircraft noise exposure and hypertension derived from a study around Schiphol Airport in 1976-1977, an increase in the number of people with hypertension is expected in the study area (table 3.1). Hypertension is a risk factor for cardiovascular diseases.

Sleep disturbance caused by airplane noise is expected to occur also. Because of large discrepancies between laboratory and field studies it is difficult to develop a sleep disturbance prediction curve. Interim dose-response curves are available though, that can be used to predict the percent of the population with reported sleep disturbance as a function of Equivalent Sound Level (L_{eq}). Because suitable exposure data were not available at the time of writing this report, no estimation has been made of the number of people with sleep disturbances.
Effects like reduced performance, increased use of medication, and an increase of babies with a reduced birth-weight may also occur. Due to the lack of clear exposure-response relations however, it is not possible to give a quantitative estimate of these effects. The current level of aircraft noise is not expected to cause noise-induced hearing loss or an increased admission to mental hospitals. Based on the literature, it is not possible to assess whether other possible effects of noise will occur, like stress, an increased cholesterol level or a decreased functioning of the immune system.

3.2 Air pollution

Components emitted during the combustion of kerosine in airplane engines include nitrogen oxides, sulphur dioxide, carbon monoxide, black smoke and fine particulate matter, polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds. The concentrations of these compounds in 1991 were calculated for an area of 20 x 20 kilometre around Schiphol airport using an OPS[1] dispersion model (table 3.3). For most components, the contribution of Schiphol airport to the total emissions of all sources in the study area is less than 10 %, and less than the contribution of road traffic. Limit values nor effect levels are exceeded. Based on these calculated levels, respiratory effects and nose and eye irritation due to air pollution from the airport, are not expected to increase. An increase in the number of people with decreased lung function is not expected either. The concentration of Benzo(a)pyrene in residential locations caused by aircraft emissions is low, less than 0,1 ng. The risk of cancer for the population in the study area caused by exposure to PAH through inhalation and ingestion is thought to be extremely low. The contribution of Schiphol airport to the total PAH levels in the study area is 12 %, less than the contribution of road traffic (see table 3.3).
Since only estimates of ambient pollutant concentrations were available, and given the public concern about air pollution and cancer in the region, additional personal exposure measurements of fine particulate matter and PAH are needed for a more conclusive evaluation of the risks of air pollution from activities on and around the airport.

[1] Operational atmospheric transport model for Priority Substances

Table 3.3 *Calculated air pollution levels in 1990 in residential areas (20x20 km around Schiphol airport), compared with limit values and background concentrations*

		Limit value ($\mu g/m^3$)	Background concentration ($\mu g/m^3$)	Concentration range (min-max, $\mu g/m^3$)
CO	98-percentile (8 hour)	6000	1000	1007-1214
NO_2	98-percentile (1 hour)	135	90	90,8-112
Benzene	annual average	10	2	2,1-2,3
SO_2	98-percentile (1 hour)	250	50	50,2-56,4
black smoke	annual average	90	40	40,2-46,4

3.3 Odour

The odour levels were calculated for an area of 20 x 20 kilometre around Schiphol based on a dispersion model and a limited number of odour measurements at different airplane engines. Volatile organic compounds are used as an indicator for kerosine odour. The results of additional odour panel measurements indicated that kerosine odour can be observed up to a distance of 8 kilometre from the airport. At the current levels of air pollution, odour annoyance was expected to occur. Differences in the individual sensitivity to odours complicate the assessment of odour annoyance while using odour limit standards. Moreover, odour standards for (air)traffic do not exist, yet. The odour concentration standard for industry and agriculture of 1 odour unit per cubic metre of air (98-percentile, 1 hour average) is exceeded in the study area. Around 108 000 residents are exposed to an odour level which is higher than this standard (table 3.1). Based on the relation between odour concentration and annoyance which is derived from a compilation of several odour studies, an average of 36 000 residents are more or less annoyed by odour emission from airport activities (table 3.1). It is not certain, however, whether the applied exposure-response relation also applies to air traffic odour.

3.4 Radiofrequent radiation

To evaluate the possible health effects of radiofrequent radiation from radars on and around the airport, data on the location and frequency of radars from the department of Air Traffic Control Schiphol Airport were used. The maximum distance at which the radiofrequent radiation from these radars can be hazardous was calculated.

The calculations show that acute health effects caused by radiofrequent radiation of the radars are not expected to occur among residents living in the vicinity of the airport.

3.5 Risk perception

The perception of hazardous activities by people living in the neighbourhood plays an important role in the well-being (and thus the health status) of the population and the acceptance of these activities. An analysis of the literature was carried out to investigate to what extent anxiety and fear in relation to air traffic can be expected among residents living in the vicinity of Schiphol airport. This concerns the fear for acute health effects caused by airplane accidents as well as the fear for long-term health impairment. The extent of anxiety depends on, for instance, the available possibilities to control the risk.

The scientific literature on the perception of safety risks related to aviation is scant. A US study among large groups of volunteers showed that the hazards of aviation are not considered to be extremely high compared to hazards of other technological activities. They are also considered less frightening than the risks of, for instance, nuclear power and the petrochemical industry.
In the past, some fear for airplane accidents was observed among residents of the Schiphol study area, but this has declined over the years. It is very likely that the crash of a Boeing in Amsterdam-Bijlmermeer, in October 1991, has increased this fear. This could give rise to an increase in stress reactions and annoyance. People might also be more likely to blame Schiphol airport for aspecific health complaints, whether justified or not. Fear for airplane accidents seems not to be related with living near or under an approach route, nor with the level of noise exposure.

Little is known about the perception of the risk of chronic health impairment in relation to aviation. Studies into the concern about health impairment caused by environmental pollution show that (media)reports on a striking increase in cases of a certain disease or about risks of environmental pollution may increase this concern. At this moment, a general increase in concern for health impairment caused by environmental pollution can be seen in the Dutch population. Residents living in the vicinity of Schiphol airport will often perceive aircraft noise, deposition of soot or kerosine odour. This may constantly feed the concern about possible health effects.

4 Current health status

4.1 Results of a small area study using hospital admission rates

We investigated spatial patterns in hospital admission rates of a few selected cardiovascular and respiratory diseases in the study area. A non-homogeneous distribution of disease and high disease ratios in the immediate vicinity of Schiphol airport were considered to be a first indication for a possible role of pollution and disturbance caused by airport activities.
Because it is not likely that environmental pollution from airport activities can cause changes in mortality, mortality figures were not studied. Local exposure to environmental pollution caused by Schiphol airport varies substantially. The health status therefore had to be studied on a small geographical scale, corresponding to 'postal code' areas ('small area study').

Preceding the geographical study, a selection of relevant health indicators, routine health registries and measuring instruments was made. The selection of health indicators was made based on the results of the pollution oriented risk evaluation. Important criteria for selection were the (biological) plausibility of the effects given exposure levels around Schiphol airport, and the number of people potentially affected. Other considerations for this selection were the concern about these effects among the residents living in the vicinity of Schiphol and research feasibility.
Only those routine health registries with morbidity data on the selected health indicators at postal code level were evaluated. The feasibility of using existing health registries was evaluated based on geographical reference (postal code), data quality, completeness, coverage and validity aspects. The Dutch Information System for Hospital Care and Day Nursing, the Dutch Obstetrics Registration and the registry of the Comprehensive Cancer Centre Amsterdam were the most suitable registries for this study. Only data from the Dutch Information System for Hospital Care and Day Nursing[2] have been analyzed, since data from the other selected registries were not available yet.

Hospitalization data for cardiovascular and respiratory diseases from the Dutch Information System for Hospital Care and Day Nursing were used to describe the health status of the population living in the vicinity of Schiphol airport. Cardiovascular effects like hypertension, acute myocardial infarction and arrythmia have been reported to be possibly related to increased noise exposure levels. Given the low concentrations of air pollutants, it is not likely that air pollution from air traffic will cause an increase in respiratory diseases. Because of the residents' concern about this issue, hospital admissions on respiratory diseases have been studied nevertheless.

[2] The Dutch Centre for Health Care Information (SIG) administrates this registry

Data were collected on the number of patients living in the study area who were hospitalized in 1991 for cardiovascular and respiratory diseases. Data were delivered aggregated per postal code of the residence of the patients. When a patient was hospitalized more than once for the same disease, only the data on first discharge were used.
Standardized morbidity ratios (SMR) were mapped per postal code area for the total EIA-study area. The disease-ratios for each postal code area have to be comparable with each other. The average disease ratios for each postal code area were therefore standardized for age, sex and size of the population, using an empirical Bayesian model with an a-priori distribution (GAMMA). This model was used to take into account sources of spatial variation. After all, the disease rate for areas with small populations can be highly affected by the random variation around the mean per area. A SMR of 120 means that the hospital admission rates in a specific postal code area is 20% higher compared to the average rate for the whole study area. A SMR of 80 means that the hospital admission rates are 20% lower compared to the average rate for the study area.

In this summary only those disease-categories are presented which are possibly associated with noise or air pollution exposure.The hospital incidence for acute myocardial infarction (ICD 410)[3] and hypertension (ICD 401-405) did not show a specific pattern, both high and low values are homogeneously distributed over the study area (see figure 4.1 and 4.2). Hospital admissions for respiratory diseases (bronchitis, ICD 490-491 and asthma, ICD 493-496) occur more frequently in areas with industrial activity like the IJmondregion, the Amsterdam-west harbour area and the Zaanregion (figure 4.3 and 4.4). In some areas around Schiphol airport, the hospital admission rates for these diseases are raised. The pattern, however, is not consistent. Higher ratios for asthma were observed in areas south of Schiphol airport, while for bronchitis higher ratios were found in areas north-east of the airport.

The hospitalization rates for cardiovascular and respiratory diseases in areas in the vicinity of Schiphol airport were not clearly higher than those in other locations of the study area. This, however, does not exclude the possibility of less severe public health effects. Only few persons with, for example, hypertension will be hospitalized. Hospital admission rates can therefore underestimate the public health impact. Data from general practitioners would have been more suitable, but were not available.
It is concluded that the results of the geographical study, no more than the results of the risk evaluation, can give a definitive answer about the effects of airport activities on public health. A disadvantage of this (ecological) study design is that only aggregated data were available instead of data on an individual level. No data were available to control for confounding variables (like tobacco and alcohol use), with the exception of age and sex. Aggregated data, however, were the only data that where reliable and available within the EIA time path.

[3] Codes according to the International Classification of diseases, 9th edition

Figure 4.1 Risk for acute myocardial infarction (ICD 410), expressed in 'smoothed' standardized morbidity ratio (SMR) per district in Schiphol study area.
(Source: Dutch Information System for Hospital Care and Day Nursing 1991 (LMR))

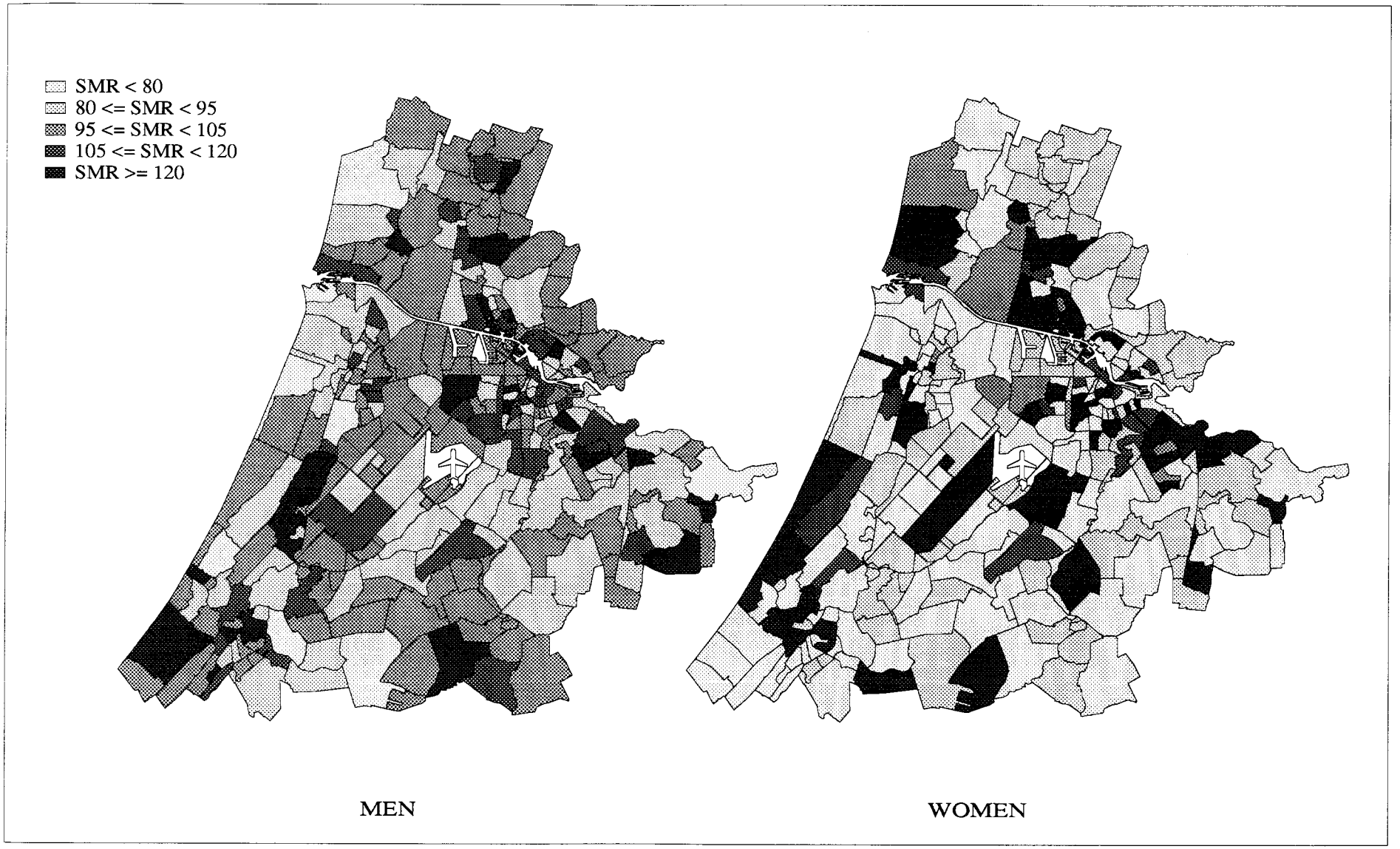

Figure 4.2 Risk for hypertension (ICD 401-405), expressed in 'smoothed' standardized morbidity ratio (SMR) per district in Schiphol study area.
(Source: Dutch Information System for Hospital Care and Day Nursing 1991 (LMR))

Figure 4.3 Risk for bronchitis (ICD 490-491), expressed in 'smoothed' standardized morbidity ratio (SMR) per district in Schiphol study area.
(Source: Dutch Information System for Hospital Care and Day Nursing 1991 (LMR))

Figure 4.4 Risk for asthma (ICD 493-496), expressed in 'smoothed' standardized morbidity ratio (SMR) per district in Schiphol study area.
(Source: Dutch Information System for Hospital Care and Day Nursing 1991 (LMR))

4.2 Analysis of complaints about noise and odour

The complaints about aircraft noise reported at the Environment Information Centre of the Environment Advisory Committee Schiphol and the odour complaints registered at the Environment Information Centre of the province of North Holland in 1992, were mapped to explore the spatial pattern in annoyance around Schiphol airport (figure 4.5 and 4.6).

About 60 000 complaints about air traffic noise were registered at the Environment Advisory Committee Schiphol (CGS) in 1992. This is much higher than in previous years (see table 4.1). The number of complainers however, did not increase as much as the number of complaints. The increase is not due to the crash of the Boeing in Amsterdam but, according to the Environment Advisory Committee Schiphol, due to the fact that several runways are more frequently used during peak load of the airport. As a result also less preferential runways, i.e. the ones causing the most annoyance, are used more frequently. Surprisingly, complaints about air traffic noise are also reported from locations at larger distance from the airport (with a noise exposure level of less than 20 Ke, see figure 4.5).

Table 4.1 *The total number of complaints and complainers registered at the Environmental Information Centre Schiphol, 1986-1993 (Source: Environment Advisory Committee Schiphol)*

Year	Complaints	Complainers	Ratio complainers/complaints
1986	2 902	1 522	1:2
1987	2 146	1 036	1:2
1988	3 875	1 614	1:2,5
1989	5 091	2 057	1:2,5
1990	55 157	3 695	1:15
1991	35 376	2 860	1:12
1992	61 043	4 580	1:13
1993*	19 143	4 433	1:4,5

* January-June

Few complaints about kerosine odour were reported at the Environment Information Centre of the province of North-Holland (see figure 4.6). This might be due to the fact that the public is unfamiliar with the information centre. Odour complaints are reported to different authorities, which leads to fragmentation.

Although the registered complaints give an impression about aspects of annoyance, they are an inadequate indicator of the full extent of noise effects on a population. Annoyance may exist without complaints and, conversely, complaints may exist without high levels of

annoyance. Complaints can give an over- as well as an underestimation of the actual community impact. Some causes of underestimation are e.g. economical alignment to the airport or feelings of distrust of authorities among residents. The formation of an 'alternative' information centre in Amsterdam-Bijlmermeer, after the Boeing crash, illustrates this latter point. Overestimation may be due to the organized submission of complaints as a means of political pressure.

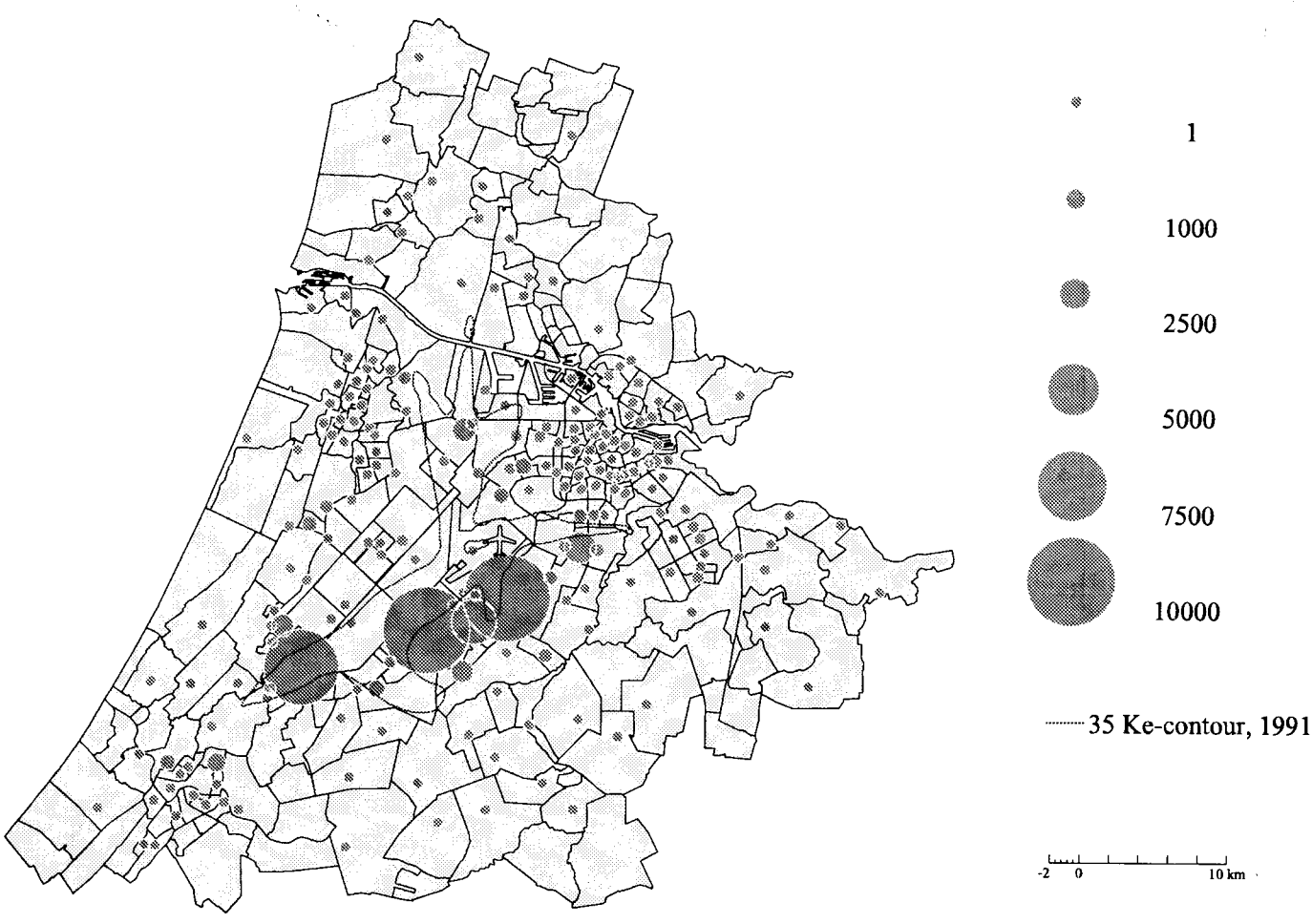

Figure 4.5 *Noise complaints; total number of complaints per postal code area in 1992 (Source: Environment Advisory Committee Schiphol; National Aerospace Laboratory))*

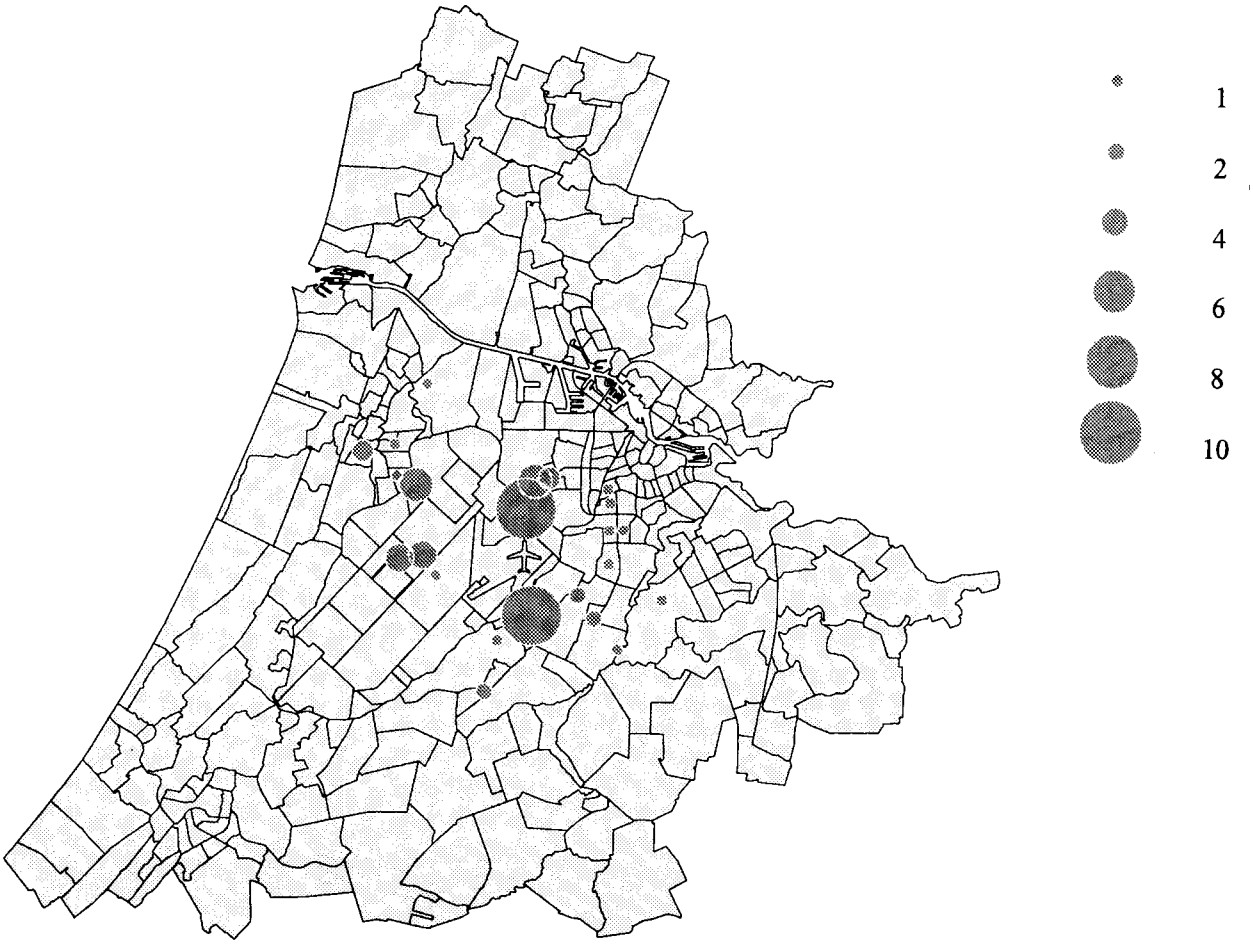

Figure 4.6 *Odour complaints; total number of complaints per postal code area in 1991 (Source: Province of North-Holland Environment Information Centre)*

4.3 Risk perception

To get insight in the risk perception a brief questionnaire-based survey was conducted in a sample of the Dutch population (936 persons) and a sample of the population living in the Schiphol study area (479 persons). This survey was conducted between March and April 1993, half a year after the crash of a Boeing in Amsterdam Bijlmermeer. The sampling method was stratified in such a way that the results are more representative for the opinions of the residents living in areas with the highest noise levels than for residents in the whole study area.

The perception and annoyance of noise and air pollution is considerably higher in the Schiphol sample as compared with the Dutch sample. Almost 75 percent of the respondents in the Schiphol study area mention air traffic as the most important source of noise, whereas 60 percent consider air traffic as a source of air pollution. Only 6 percent of the Dutch sample mention air traffic as the most important noise source. The concern about long-term health effects is also higher among respondents in the Schiphol sample than in the Dutch population. Residents of the Schiphol area are more often afraid that their health will be affected by noise and air pollution. It is striking that respondents in the study area more often mention lung cancer as a possible health effect of air pollution and also noise.

In the literature, no association was found between living near the airport or underneath an approach route (expressed in noise levels) and fear for a plane crash in a residential area. Residents living in the vicinity of Schiphol, however, are more afraid of plane crashes compared with the general Dutch population. Residents of the Schiphol area also assessed living in the vicinity of an airport or under an approach route as more dangerous.

In addition to the questionnaire, a subgroup of the Schiphol sample has been interviewed. This group consisted of people who (as indicated in the survey) thought of the residential environment of an airport as a hazardous situation or, in contrast, not hazardous at all. The results of the interviews do not reflect the opinion of all the residents of the Schiphol area, since only a total of 66 persons have been interviewed. Additional interviews were held with a number of key persons (e.g. general practitioners, town-councillors) in the Schiphol area who are well acquainted with matters of public concern.

The results of the interviews show that the Bijlmermeer calamity made people aware of the possibility of a plane crash in their surroundings. The extent to which feelings of fear occur differ from place tot place. Particularly children who witnessed the crash show a strong fear for air traffic, especially in the evening. Soon after the Bijlmermeer crash, intense emotional reactions were observed among some residents in the northern part of Aalsmeer and the Haarlemmermeer, but these reactions have diminished very fast. Since then, however, people are more aware of aircraft movements or noises.
Some respondents are permanently afraid, whereas others worry about the increasing number of flights, or are concerned in case of unusual events. Respondents who live at a greater distance from the airport, however, feel safe most of the time.

The respondents stated that they experience the development of Schiphol airport as an inevitable process in which their interests are not, or only partially, taken seriously. Residents, however, are not much inclined to leave the region, because of social and economical ties.

An important conclusion from these interviews, is that the information on safety risks provided by the airport authorities is looked upon with considerable distrust. People believe that information about the risks of air traffic is withheld on purpose. Recently, however, some improvements have been noted. There is a need for honest information on safety risks and health hazards provided by independent organizations.

5 Recommendations for further research

Further research is recommended for the following reasons. In the first place, this health assessment only gives a fragmentary view of the health status of residents living in the vicinity of Schiphol airport, due to the limited time and data available. Not all relevant health effects could be studied. For a better understanding of the health impact of environmental pollution caused by airport activities, it is recommended to perform additional studies of the current health status of residents living in the vicinity of Schiphol airport in relation to the (personal) exposure.
Also more epidemiologic studies are needed for investigating the relationships between the extent of noise exposure and important health effects, like sleep disturbance and decreased performance.
At present, it is not possible to predict the health impact of future expansions of the airport. For this reason, according to the terms of reference, the residents' health status must be monitored during the period of airport expansion.

5.1 Short-term research

In the first place, studies using data from routine health registries are recommended. The study on hospital admissions for certain cardiovascular diseases should be extended to investigate spatial correlation between hospital admission and data on noise and air pollution levels. Furthermore, additional research on medication use, cancer incidence, and (possibly) the occurrence of reduced birth-weight is recommended, using data from existing health registries. In the second place, cross-sectional studies in the population living in the vicinity of Schiphol airport are needed to assess the occurrence of sleep disturbance, annoyance and decreased performance in relation to aircraft noise. Sleep disturbance among adults and performance among children should be investigated using sleep quality measurements and neuropsychological tests on memory and capacity to concentrate, in combination with noise measurements. The number of people annoyed by noise and odour should be determined by a questionnaire-based survey. The results of these studies will form the basis for prospective studies and the development of a monitoring system for the health status and policy measures to be taken.

Data on the actual noise exposure levels and other forms of environmental pollution exposure around Schiphol airport are very limited. Additional measurements are therefore needed to determine whether the calculated noise and odour levels are representative for the actual exposure of residents.
Exposure to polycyclic aromatic hydrocarbons and fine particulate matter should be studied, as well as the quality of indoor air in noise insulated houses.

5.2 Monitoring

In order to detect changes in environmental quality and the health status of the population in the case of airport expansion, a monitoring system is recommended. This is also recommended, among other things, in the advisory reports of the Environmental Impact Statement Committee and the State Inspectorate of Public Health.
In a monitoring system data can be collected and analyzed continuously and systematically. Units of observation can be a group of people or an individual. For a monitoring system three kinds of data are required. Data on the exposure to noise, odour and (possible) air pollution by airport activities and other sources must be collected, specified by time and place. Secondly, basis data about the population studied are needed (for instance on demography and life style). In the third place, specific data on the health status are required. Health effects considered eligible for a monitoring study are (tentatively) sleep disturbance and performance, cardiovascular diseases, medication use, annoyance, and self-perceived health. A more definitive choice of the effects to be monitored will be made based on the results of the sleep-disturbance, performance and annoyance studies, and the studies using data from routine health registries. Preceding the design of the actual monitoring system a feasibility study will be carried out.

General practitioners seem to be an important data source for most health indicators studied. Unfortunately, in the Netherlands there is not an appropriate registration system available yet. A monitoring system is therefore proposed that partly uses data from current health registries (e.g. cancer and pharmacist registries) and partly newly developed registration systems (general practice registry). The general practice registration to be developed should be linked to an existing general practice sentinel station in the Schiphol region, supplemented with a few new locations with different environmental pollution.

The health status of the population can be monitored using data from general practices, in combination with periodical surveys, and studies using data from routine registries. If necessary, the sleep disturbance and performance studies can be repeated. Patient data on (self-perceived) health supplemented with data on risk factors other than environmental pollution, like life style and housing conditions, can be collected with a validated questionnaire. Finally, a periodical survey of the occurrence of noise and odour annoyance and the perception of residential conditions is recommended.

6 Main conclusions and recommendations

Based on the results of the risk evaluation the following health effects due to aircraft may occur among residents living in the vicinity of Schiphol airport: annoyance, sleep disturbance, reduced performance, cardiovascular disease and possibly, as a result of these effects, an increased use of medication. Other possible effects of noise, like hearing loss, are not expected to occur. It is unlikely that air pollution related to airport activities will cause an increase in respiratory effects or cancer. Odour annoyance is likely to occur, however.

The analysis of hospital data do not indicate higher rates of hospitalization for cardiovascular and respiratory diseases in the vicinity of Schiphol airport as compared to more distant areas. The findings for respiratory diseases are in agreement with the results of the risk evaluation, but those for cardiovascular diseases are not. These findings do not exclude however the occurrence of non-clinical effects, that might be expected according to the literature. In the Netherlands people with health complaints are in first instance usually treated by general practitioners. Only the more severe or complicated cases are admitted in a hospital. Hospital admission rates can therefore result in an underestimation of the effects on public health.

The results of the survey show that residents of areas surrounding Schiphol airport are more frequently annoyed by noise and air pollution than a sample of the general Dutch population. Respondents from the Schiphol area indicated that air traffic was the main source of noise and air pollution in this area. The concern for long-term health effects caused by these pollutants was also greater in the Schiphol area than in the general population. Fear for an airplane accident was more frequent among residents of the Schiphol area than among the Dutch population. Residents of the Schiphol area also assessed living in the vicinity of an airport or under an approach route as more dangerous.

In-depth interviews with a small number of residents show that respondents did not trust the information provided by the (airport) authorities on the hazards concerning safety and health. Residents believed that information about the hazards of air traffic has been withheld on purpose. Recently, however, some improvements in the information provided by the (airport) authorities have been noted by the respondents.

The Health Impact Assessment shows substantial gaps in knowledge about the actual exposure levels of pollution in the vicinity of Schiphol airport and about exposure-response relations. In particular, conclusive information on the relation between noise and health effects such as sleep disturbance and effects on performance is lacking. This complicates a full estimation of the extent to which health effects can occur at current levels of pollution.

Further research is recommended to enlarge insight in the current health status of the population living in the vicinity of Schiphol airport, i.e. a study on sleep disturbance and annoyance among adults and on performance among children. In addition, further studies

on the incidence of cardiovascular diseases, medication use, cancer, and the incidence of decreased birth weight using health data collected on a routine basis should be performed. These recommendations not only reflect the identified gaps in knowledge, but also cover issues with high public concern (e.g. cancer and decreased birth-weight).

Because of the many uncertainties in the relation between environmental pollution related to airport activities and health effects, it is not possible to give a quantitative estimation of the health status in the case of airport expansion and changes in environmental quality. Additional research in which the impact of airport activities on the environmental pollution and the health status is being monitored, is therefore recommended. A monitoring system using data from general practitioners is recommended in combination with periodical surveys and studies using health data from routine registries. The following health effects should be monitored: sleep disturbance and performance, cardiovascular diseases, medication use, annoyance and self-perceived health.

A more definite choice of the design of this monitoring system will be made based on the results of the sleep-disturbance and performance study, and the studies using health data from routine registries. It is recommended to have the design, the interpretation, and the results of the health impact studies reviewed by independent experts.