RIVM Report 550012003/2004

Environmental (in)equity in the Netherlands
A Case Study on the Distribution of
Environmental Quality in the Rijnmond region

H Kruize and AA Bouwman

Erratum (see page 2),
September 2004

This investigation has been performed by order and for the account of RIVM, within the framework of project S/550012, 'Population and Health', and by order and for the account of the Ministry of Public Housing, Physical planning and the Environment (VROM-DGM-LMV) within the framework of the RIVM-project M/830950, 'Policy-Supporting Instruments'.

RIVM, P.O. Box 1, 3720 BA Bilthoven, telephone: 31 - 30 - 274 91 11; telefax: 31 - 30 - 274 29 71

Erratum for RIVM rapport nr. 550012003

Due to improper coding of data the percentages for 'Accumulated noise level less than 50 decibels' and for 'Available public green areas' in **Table 4.1** on **page 25** are wrong. The new percentages do not lead to other conclusions in this report. The statement that environmental quality is worse in the Rijnmond region compared to the Netherlands in general holds.

The correct percentages are:

	the Netherlands	
	not weighted	*weighted*
Accumulated noise level less than 50 decibels (dB(A))	24.9	36.9
Available public green areas < 50 m^2 per inhabitant within a distance of 500 metre	87.9	86.4

Abstract

As a part of a broader investigation on environmental inequity in the Netherlands, an exploratory case study on the socio-economic distribution on (perceived) environmental quality was carried out in the Rijnmond (industrial and urbanised) region in the western part of the Netherlands. Disparities in local environmental quality with respect to noise, air pollution, availability of public green areas, safety risks, and presence of waste disposal sites, were analysed separately and accumulatively across income levels making use of zip codes. Inhabitants' perception of environmental quality with respect to spatial and income differences was also ascertained and analysed. Recent, available national and regional databases and literature were used for the analyses. Disparities in local environmental quality were found to be linked to income level, especially for air pollution and the availability of public green areas. In addition, accumulation of environmental 'goods' (high-quality environmental conditions) were found more often in high-income than in low-income areas. Inhabitants of Rotterdam also mentioned littering and dog mess to be the greatest environmental problem. All income categories experienced annoyance, but from different, often area-specific sources. Considering these results, policy-makers are advised to take into account the effects of their policy on different income categories.

Preface

In 2000, the National Institute for Public Health and the Environment (RIVM) stated in the National Environmental Outlook that quality of the local environment in the Netherlands is often worse in the older urban neighbourhoods, compared to newer neighbourhoods in rural areas (e.g. National Environmental Outlook 5, 2000). These older urban neighbourhoods are often inhabited by lower income people. As a result of these findings the RIVM wanted to explore if low-income people are indeed exposed to a worse environmental quality in their neighbourhoods compared to high-income people in the Netherlands. Therefore, they performed an exploratory research if there were any differences in local environmental quality between zip code areas with a different income level. The results, as presented in the Environmental Balance of 2001, indicated that low-income areas were built more densely, were situated more often in the proximity to a road were the NO_2 standard was exceeded, and were exposed to higher noise levels than high-income areas (RIVM, 2001). To get further insight in this issue of so-called environmental inequity in the Netherlands, the RIVM and the Copernicus Institute for Sustainable Development and Innovation (Utrecht University) started a PhD project on this topic. In this project, performed by Hanneke Kruize (RIVM), the socio-economic differences in local (perceived) environmental quality and causes of these differences are analysed, with an emphasis on the effects of (environmental) policy. The case study presented in this report is a part of that project, and is still ongoing. Therefore we do not suggest giving a complete insight on the issue of environmental equity in the Netherlands in this report. It rather serves as a discussion document.

Many colleagues at the National Institute of Public Health and the Environment (RIVM) and the Utrecht University have been involved in the case study so far in providing data or knowledge. Among these people are the advisory committee of the doctoral research (Professor N.D. van Egmond (RIVM), Professor dr. P. Glasbergen (Utrecht University), Dr. P.J.J. Driessen (Utrecht University), Dr. M. Kuijpers (RIVM), Dr. A.E.M. de Hollander (RIVM) and Dr. R.van der Wouden (Dutch Spatial Planning Agency)), and Rebecca Stellato (RIVM, statistical expert). We would like to thank all of them for their useful help and hope we may ask for their help in the future again.

This report is an adapted version from the paper presented at the OECD Workshop on the ‘Distribution of Benefits and Costs of Environmental Policies’ organised by the National Policies Division, OECD Environment Directorate (OECD, 4-5 March 2003, Paris). We thank the OECD for the opportunity to take part in this workshop and for their useful comments.

Contents

Samenvatting

In het kader van een verkennend casusonderzoek naar de sociaal-economische verdeling van lokale (ervaren) milieukwaliteit in de regio Rijnmond zijn verschillen in lokale milieukwaliteit geanalyseerd voor geluid, luchtverontreiniging, beschikbaarheid van groen, risico's door industriële activiteiten en vuurwerkopslag, en aanwezigheid van afvalverwerkingsbedrijven voor postcodegebieden met een verschillend inkomensniveau. Daarnaast is de beleving van de milieukwaliteit van bewoners vastgesteld en geanalyseerd op ruimtelijke verschillen en verschillen tussen inkomensgroepen, en is de relatie tussen de 'objectieve' milieukwaliteit (bijv. geluidniveaus, aantal woningen binnen een risicocontour) en 'subjectieve' milieukwaliteit (bijv. geluidhinder, onveiligheidsgevoel door aanwezigheid industrie) verkend. Hiervoor werden ruimtelijke gegevens uit bestaande nationale en regionale bestanden gebruikt. De ruimtelijke verdeling van de lokale milieukwaliteit en inkomen werd geanalyseerd met behulp van een Geografisch Informatie Systeem (GIS). Verschillen in lokale (ervaren) milieukwaliteit tussen sociaal-economische groepen zijn geanalyseerd op basis van statistische analyses. Voor ervaren milieukwaliteit werden tevens in literatuur gerapporteerde resultaten van lokaal en regionaal onderzoek gebruikt.
Op basis van de resultaten van ons onderzoek lijken gebieden met een hoger inkomensniveau een betere milieukwaliteit in hun directe omgeving te hebben dan gebieden met een lager inkomensniveau, met name met betrekking tot luchtverontreiniging en beschikbaarheid van publiek toegankelijk groen. Verder kwamen positieve aspecten (bijv. aanwezigheid van groen, lagere niveaus van geluid en luchtverontreiniging) vaker tegelijk voor in hogere inkomensgebieden dan in lagere inkomensgebieden. Bewoners van alle inkomensklassen ervoeren hinder, maar wel van verschillende, vaak locatiespecifieke bronnen.
Dit casusonderzoek maakt deel uit van een breder promotie onderzoek naar milieu en sociale ongelijkheid ('environmental inequity') in Nederland, met aandacht voor de rol van beleid hierin, en een discussie over bestaande perspectieven ten aanzien van 'environmental justice'.

Summary

As a part of an exploratory case study on the socio-economic distribution on local (perceived) environmental quality in the Rijnmond region, a highly urbanised and industrialised region in the western part of the Netherlands, disparities in environmental quality were analysed for noise, air pollution, availability of public green areas, safety risks, and presence of waste disposal sites for zip code areas with a different income level. Furthermore, perceived environmental quality of the inhabitants was assessed and analysed on spatial and income differences, and the relation of perceived environmental quality (e.g. noise annoyance, unsafety feelings due to industrial activities) with environmental quality determined using ‘objective’ indicators (e.g. noise levels, number of dwellings within a risk contour). Spatial data were collected from recent existing national and regional databases. The spatial distribution of the local environmental quality and income was analysed using a Geographic Information System (GIS). Socio-economic differences in (perceived) local environmental quality were assessed based on statistical analyses. For perceived environmental quality results of local and regional research on this topic, reported in literature, were used as well.
The results indicate that disparities were present for zip code areas with a different income level, especially for air pollution and for availability of public green. In addition, accumulation of environmental ‘goods’ or amenities occurred more often in high-income areas than in low-income areas. Higher income areas thus appeared to have a better environmental quality and showed a higher access to environmental amenities than lower income areas. Furthermore, inhabitants of all income categories experience annoyance, but from different, often area-specific sources.
This case study is a part of a broader investigation on environmental inequity in the Netherlands, including research on the role of policy in it and a discussion on environmental justice perspectives.

1. Introduction

In this chapter the context and the aim of the case study on the socio-economic distribution of (perceived) environmental quality in the Rijnmond region, the Netherlands, is described. Furthermore, the structure of the report is pointed out.

1.1 Context and aim of the case study

In 2000, the National Institute for Public Health and the Environment (RIVM) stated in the National Environmental Outlook that quality of the local environment in the Netherlands is often worse in the older urban neighbourhoods, compared to newer neighbourhoods in rural areas (e.g. National Environmental Outlook 5, 2000). These older urban neighbourhoods are often inhabited by lower income people. As a result of these finding the RIVM wanted to know if low-income people are indeed exposed to a worse environmental quality in their neighbourhoods compared to high-income people. Therefore, they performed an exploratory research on differences in local environmental quality between zip code areas with a different income level. The results, presented in the Environmental Balance of 2001 and below in Table 1.1, indicated that low-income areas were built more densely, were situated more often in the proximity to a road were the NO_2 standard is exceeded, and were exposed to higher noise levels than high-income areas (RIVM, 2001).

Table 1.1 Differences in environmental quality between income categories in the Netherlands

Income category	**High**	**Above average**	**Average**	**Low**	**Minimum**	**Mixed**	**All levels**
	%						
Environmental indicator							
More than 35 dwellings per hectare	22	36	49	63	68	46	47
Proximity to green space	17	13	12	13	12	12	13
Infrastructural barrier	9.8	11	11	9.9	9.5	10	10
Proximity to road with NO2 exceedance	16	15	19	27	33	21	20
Noise > 50 dB(A)	80	81	82	84	85	82	82
Noise > 65 dB(A)	3.8	3.7	4.1	4.4	5.3	4.6	4.2
Proximity to ESR/ fireworks[1)]	0.5	0.8	1.1	1.2	0.9	1.0	1.0

Source: RIVM. *RIVM/MC2001*
1) ESR establishments and firework storage depots.

To get further insight in this issue of so-called environmental inequity in the Netherlands, the RIVM and the Copernicus Institute for Sustainable Development and Innovation (Utrecht University) started a PhD project. In this project, performed by Hanneke Kruize (RIVM), the socio-economic differences in local (perceived) environmental quality and causes of these differences are analysed, with an emphasis on the role of (environmental) policy. The case study presented in this report is a part of that project and is also performed as a part of the OECD (Organisation on Economic Coordination and Development) programme 'The Social and Environmental Interface: Enhancing the Quality of Life'. The results of this study were used in an OECD workshop on the Distribution of Benefits and Costs of Environmental Policy (March 4-5 2003, Paris) organised as a part of their programme.

Figure 1.1 is presented to give insight in the part of this case study within the context of the larger research. The grey circle indicates the focus of this case study. It makes clear that the aim of this report is to describe differences between socio-economic groups in (perceived) environmental quality in their neighbourhood, in other words, the socio-economic distribution of local (perceived) environmental quality. This is both done for separate aspects of environmental quality, such as noise, air pollution and access to public green areas, and for the accumulation of these aspects. Although not explicitly included in this figure, we pay attention to the perception of inhabitants concerning environmental quality in their neighbourhood as well. We will come back to that later in chapter 2.

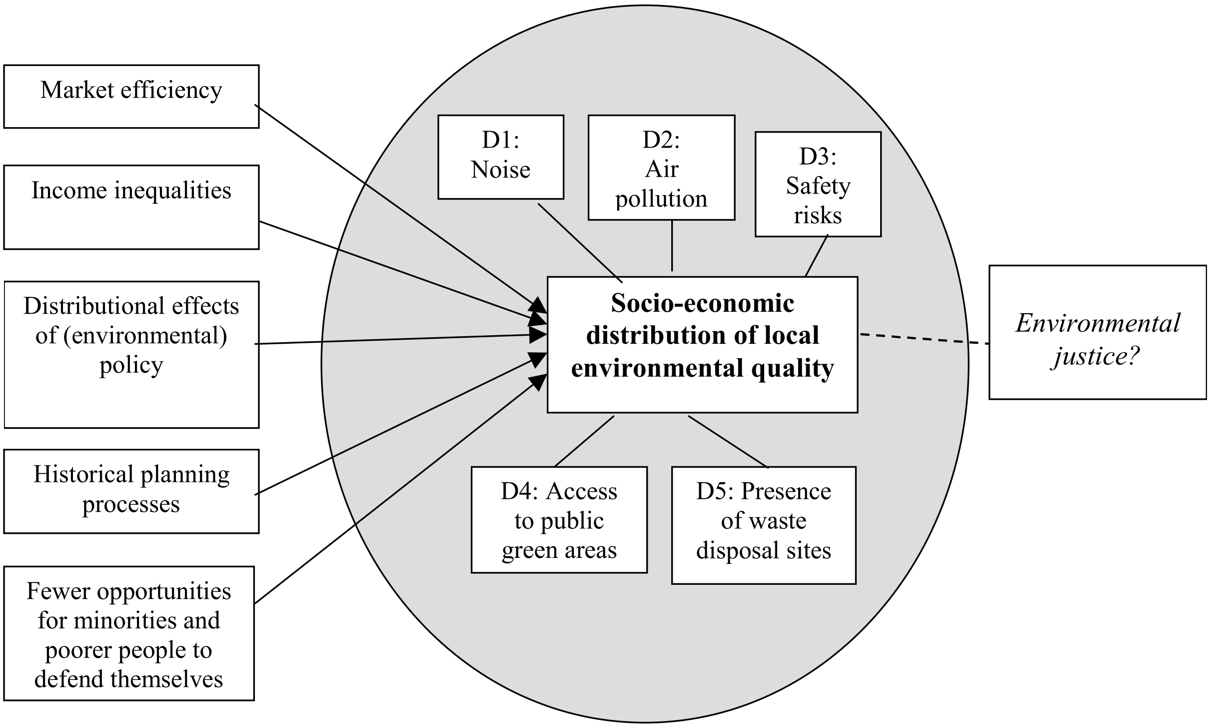

Figure 1.1. Analytical model for the Rijnmond case study

In this case study we will give special attention to the methodological issues related to analysing the socio-economic distribution of environmental quality. We will give our recommendations on these issues as well. This reports presents the current results of a case study in the Rijnmond region that is still going on. As mentioned before, the case study itself is a part of a larger study on environmental (in)equity in the Netherlands performed at the RIVM and the Utrecht University. Therefore, this report does not suggest giving a complete insight on the issue of environmental equity in the Netherlands and might rather serve as a discussion document for further research.

1.2 Report structure

The selection and definition of indicators used to describe the socio-economic distribution will be explained in the second chapter. In the third chapter the selected study area is described. The fourth chapter deals with data collection and data availability, and the methods used in this study. The results are presented in different chapters, each chapter describing one topic concerning the socio-economic distribution of environmental quality. Chapter five presents the spatial distribution of the selected indicators. The socio-economic distribution of environmental quality in the Rijnmond region is reported for separate environmental indicators in chapter six. Chapter seven shows the socio-economic distribution on accumulation of environmental 'bads' and 'goods'. Chapter eight focuses on the perception of inhabitants on the environmental quality in their neighbourhood and region. Differences in perceived environmental quality between income categories are described, and the association with the so-called 'objective' data is investigated. Finally, we discuss the results and methodological issues of this case study and we give an indication what research directions would be interesting to improve the insight in the socio-economic distribution of environmental quality in chapter nine.

2. Selection and definition of indicators

2.1 Selection of indicators

The selection of indicators in this report is based on our conceptual ideas, but also on requirements from the OECD for their workshop (see also p.14). As described in Section 1.1, the aim of the case study was to assess the socio-economic distribution of environmental quality based on empirical data. The OECD requested that the distribution should focus preferably on the household level, and socio-economic categories should in the first place be defined by income. Based on the aim of the case study, we defined two main categories of indicators, namely *environmental indicators* and *socio-economic indicators.*

The first category, the *environmental indicators*, includes the indicators for which a socio-economic distribution was described. Environmental quality might be defined in a strict way, including air quality, soil quality and noise for example, or in a broader way, including aspects such as availability of public green areas as well. In this case study we chose the latter approach. Most studies included only one environmental aspect, but including more aspects in the same case study gives, in our opinion, a more complete insight in the socio-economic distribution of environmental quality. In addition, it is possible to assess if there are areas with an accumulation of either environmental problems or access to environmental amenities, thus areas where several environmental problems or environmental amenities occur at the same time. Presence of waste disposal sites was added because in American studies on environmental justice the presence of a hazardous waste site is often used as an environmental indicator. By including this variable we figured we could eventually make comparisons with the results of these studies.
Environmental quality can be described using both ‘objective’ data and ‘subjective’ data. ‘Objective’ data are data that, when generated by different persons using the same methods, are the same. ‘Objective’ data are often used for evaluation or planning processes, for example by policy makers, to get insight in the (predicted) state of for example the local environment. ‘Subjective’ data are important to get insight in the feelings and attitudes of inhabitants about their local environment and in what they consider important in this environment. These data give insight in the needs of people and the extent to which they are met. This perception is not only related to the ‘objective’ characteristics of the environment, but also to personal and contextual aspects (Van Kamp *et al*., 2003). Examples of ‘objective’ data are noise levels and square metres of public green areas within a distance of 500 m of each person’s house. Examples of ‘subjective’ data include the satisfaction with the amount of public green areas in the neighbourhood and noise annoyance. We think that including the perception of people adds insight in the role of environmental policy in the occurrence of socio-economic differences in local environmental quality. Furthermore, it might give insight

in what aspects of the environment should be improved to make the quality of the local environment of people more liveable.
The second category of indicators is the category of *socio-economic indicators*, defining the socio-economic component for which the distribution is described, in this study being income indicators.
This resulted in the selection of indicators presented in Table 2.1.

Table 2.1 Selection of indicators

Type of indicator	Indicator
(' Objective') environmental indicators	Air quality Noise quality Soil quality Safety risks from industrial activities, fireworks and transport Waste disposal sites in direct surroundings Availability of public green areas (e.g. parks, forest)
Indicators for perceived environmental quality	Perception of environmental quality (air pollution, noise, soil) in the neighbourhood Perception of availability and quality of public green areas in the neighbourhood
Socio-economic indicator	Income

2.2 Making the indicators operational

We made the selected indicators operational, or in other words, we defined them based on several criteria. In the first place, the definition of the indicators should add information to the aim of the case study, namely assessing the socio-economic distribution of environmental quality. In the second place the OECD made a distinction in environmental 'goods' (access to environmental amenities) and 'bads' (e.g. high levels of air pollution and noise, presence of risky activities).
In addition, we think disparities can be considered in several ways.

- First it could be approached from a very basic 'protection of general human rights' level (e.g. defined in the Dutch Constitution). Each Dutch citizen should be treated equally; no distinction should be made based on religion, ethnicity, etc.We translated this into 'no disparities should exist between income categories in environmental quality'. It might be evaluated by comparing the distributions, means or percentages of each socio-economic category with each other to see if there are differences.
- Second, one could take a minimum local environmental quality at which health and safety are protected as a starting point. Environmental laws and standards may define this minimum quality. Levels above this standard could be defined as an environmental 'bad'.

To analyse disparities, one might compare how often ‘bads’ are present for different socio-economic categories.

- A third approach is that a ‘nice and pleasant’ type of local environment, meaning not only a guarantee for protection of health and safety, but also a type of local environment in which people feel comfortable, a liveable type of local environment. It might be defined as the access to environmental amenities or environmental ‘goods’, things that make people’s local environment a nice and pleasant surrounding. Unless target values are available, a value needs to be chosen to be able to analyse disparities. This value might be set based on expert judgement, or on e.g. surveys on satisfaction or annoyance. Disparities could then be analysed by comparing how often the present level of an environmental indicator is below the target value, or the amount of people being satisfied or not annoyed.

Naturally, the possibilities for defining an indicator in the most optimal way are limited by data availability. The way in which we defined the indicators in this case study is summarised in Table 2.2 and in Appendix 1A and 1B.

Table 2.2 Definition of indicators for the Rijnmond case study, using three different approaches

	Noise	**Air pollution**	**Availability of public green areas**	**Safety risks**	**Presence of a waste disposal site**
'Basic' approach	Mean noise level	Mean level of NO_2	Mean m^2 of public green areas available per inhabitant	Mean % of dwellings within a safety risk contour	% of areas with a waste disposal site within 500 m
Environmental 'bads'	Noise level > 65 decibel (dB(A))	Level of NO_2 > 40 $\mu g/m^3$	< 50 m^2 of public green area available per inhabitant within 500 m	% of areas with dwellings present within a safety contour	% of areas with a waste disposal site within 250 m
Environmental 'goods'	Noise level < 50 dB(A)	Level of NO_2 < 40 $\mu g/m^3$	> 50 m^2 of public green area available per inhabitant within 500 m	% of areas with no dwellings within a safety risk contour	% of areas without a waste disposal site within 1000 m

3. The Rijnmond region: general characteristics

The Rijnmond region was selected as the study area for this case study (Figure 3.1). It is a mainport, an industrialised and urbanised area of 800 km^2 in the western part of the Netherlands, inhabiting almost 1.2 million people in 18 communities (DCMR, 2002), causing spatial pressure. It also includes one of the largest cities of the Netherlands, Rotterdam. This is a multicultural city, with many minorities from Turkey, Morocco and other North African countries, Suriname, Cape Verdians, and the Antilles. In Rotterdam about thirty percent of the population belongs to these groups of minorities (COS, 2003). Furthermore, the largest industrial harbour of the world is located in this region. Because of the presence of this harbour there are about 22,000 (industrial) companies of above average size, with activities in the field of chemical products, energy production, and transport, among other activities. The harbour and the industry are mainly located along the 'Nieuwe Maas' river, which divides the Region into two parts (Figure 3.1). The harbour is western from the city of Rotterdam. In addition, the region inhabits horticulture, nature and recreation. Furthermore, there is an airport (Rotterdam airport), with 93,170 flights and 826,889 passengers in 2001 (source: Rotterdam Airport), at the northern side of Rotterdam. These activities cause a lot of transportation on both water and land. There are important highways in the Rijnmond region. As a result, traffic and industry are an important source of pollution in this area. Other sources of pollution are aircraft, agriculture and horticulture, and the consumer (DCMR, 2002).

The Rijnmond region consists of both heavily urbanised areas as well as rural areas. This potentially results in a higher variety in socio-economic groups and environmental quality than in case one would focus only on the city of Rotterdam, for example. Based on these facts, together with the fact that there appeared to be many useful data, we selected this area. Focussing on a specific area makes it possible to go in more depth and analyse potential causes of the socio-economic differences in local environmental quality in more detail in the future.

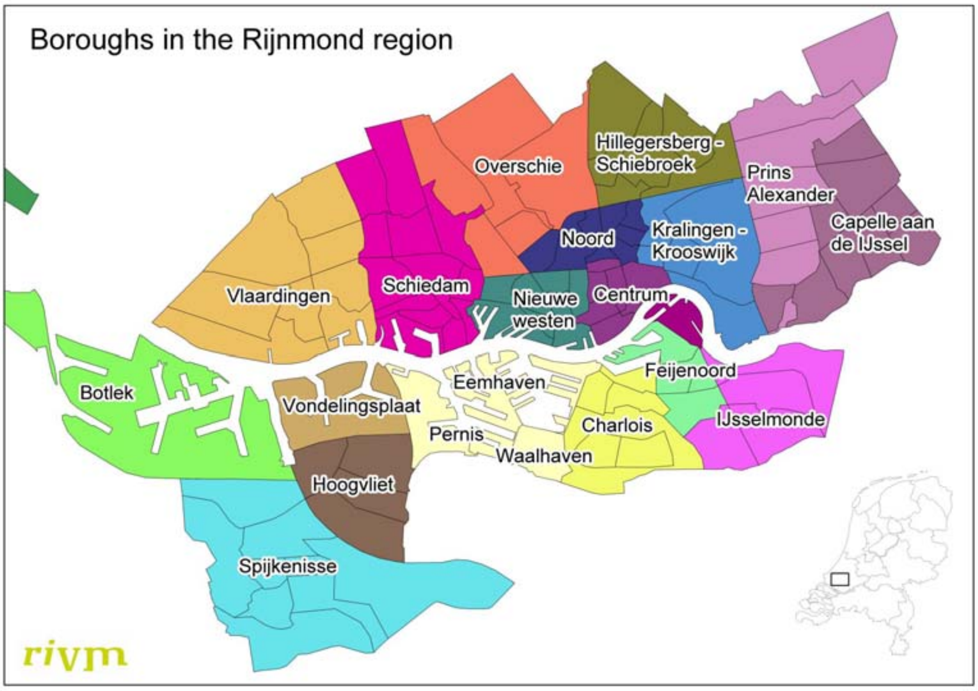

Figure 3.1 Study area: Rijnmond region ('regio Rijnmond'), with the boroughs (coloured areas) and 4-digit zip code areas (areas within the boroughs) indicated. At the right site the square box indicates the location of the region within the Netherlands.

4. Data and methods used to describe the distribution of environmental quality

In the first section of this chapter the process of data collection and data availability is described. In addition, general statistics of the available data are presented on each spatial scale level (6-digit and 4-digit zip code) separately. In the second section methods used to analyse the data are explained generally.

4.1 Data collection and data availability

In order to describe the distribution of environmental quality, quantitative data were collected for the selected indicators (Table 2.1) at the lowest possible spatial scale level, preferably on the household level. If no data were available at that level, the 6-digit zip code level, about the size of a street, was the second option for data collection. This is still a good option, because at this level the differences in local environmental quality for indicators such as noise and air pollutants like NO_2 are clearly visible. If no data were available on the neighbourhood level and 6-digit zip code level, data were collected on the 4-digit zip code level, with the size of several neighbourhoods, and the borough level, with the size of several 4-digit zip code areas. However, at these levels diversity in environmental quality and in income is often wiped out.

National databases, available at the RIVM, were screened for useful data, because this would offer similar data for the Rijnmond region. Furthermore, it would offer the possibility of expanding the analyses to a larger part of the Netherlands, which will be done as a part of the larger environmental equity study mentioned before. In case no data were available from these databases, regional or local data owners were approached. Data were available on different spatial scale levels (see next chapters). Appendix 1A displays the definition of indicators based on the data available at the 6-digit zip code level, the data source and the year of data collection.

For analyses on the 4-digit zip code level 6-digit zip code data on the environmental indicators were aggregated to the 4-digit level, by averaging the values for all 6-digit zip code areas within a certain 4-digit zip code area. These data were combined with additional data available on the 4-digit zip code level (Appendix 1B). On the 4-digit level the indicator for income could be defined in four different ways, based on the available data. These differently defined income indicators were highly correlated (Appendix 2).

Data on indicators on perceived environmental quality were only available at a higher spatial scale level, namely the level of boroughs (see Figure 3.1). To analyse them in combination with the objective data, we assumed the perceptions available on the level of a borough to be valid for all 4-digit zip code areas within the borough.

4.2 General description of the available data

Appendix 3 gives a general description of the data. Data were present for 19,495 6-digit zip code areas for most indicators. Table 4.1 shows comparisons of the Rijnmond region with the Netherlands for some of the indicators to get a general idea to what extent the Rijnmond region matches with the Netherlands as a whole. Percentages are presented both not weighted and weighted for the number of inhabitants living in each area to get insight in potential differences caused by weighing. Weighing was applied because in areas with more inhabitants the environmental quality present has an impact on more people.
The average income level is lower in the Rijnmond region compared to the general Dutch population, and the main stage of life per 6-digit zip code area in the Rijnmond region is a little bit younger. In the Rijnmond region the housing density is much higher than in the Netherlands as a whole. In general, environmental quality is worse in the Rijnmond region compared to the Netherlands in general.
Weighted percentages differ a little from the unweighted percentages, and to a larger extent for an accumulated noise level below 50 dB(A) in the Netherlands.

Appendix 4 describes general statistics for many of the indicators for which data were available on a 4-digit zip code level, including the aggregated data on environmental indicators. Data were available on more than a hundred 4-digit zip code areas.

Table 4.1 Comparisons between the Rijnmond region and the Netherlands on some of the selected indicators (% of 6-digit zip code areas)

Indicator	Rijnmond region		the Netherlands	
Income	*not weighted*		*not weighted*	
- high	5.3		8.3	
- above average	16.5		23.3	
- average	34.0		38.3	
- low	20.0		13.4	
- minimum	8.3		4.2	
- various	7.5		8.7	
- unknown	8.5		3.8	
Stage of life				
- starters	1.3		1.3	
- young people	5.6		4.2	
- couple with young children	21.0		18.6	
- couple with older children	24.2		30.5	
- elderly	27.9		29.8	
- completed	10.3		10.9	
- various	1.1		0.7	
- unknown	8.7		4.0	
Percentage of areas with a housing density > 35 dwellings/ha	75.1		38.8	
	not weighted	*weighted*[1]	*not weighted*	*weighted*[1]
Accumulated noise level more than 65 decibels (dB(A))	8.8	7.7	5.4	6.0
Accumulated noise level less than 50 decibels (dB(A))	9.3	10.9	75.1	63.1
Available public green areas < 50 m^2 per inhabitant within a distance of 500 metre	87.2	88.8	12.1	13.6
Average percentage of dwellings within a safety contour	5.1	3.8	1.0	1.0

[1] weighted for the number of inhabitants in each 6-digit zip code area

4.3 Methods of analysis

In general, two methods of analysis were used, namely spatial analyses and statistical analyses. Spatial analyses were performed in a Geographical Information System (GIS). The available spatial data for each indicator were entered into GIS maps. These maps were used to analyse the spatial distribution of the selected indicators. For some indicators data were already connected with a 6-digit or 4-digit zip code (the units for the statistical analysis). For other indicators, such as noise and air pollution, spatial information needed to be connected to 6-digit zip code for the statistical analysis. This connection was made by overlaying a GIS map with the spatial data of e.g. noise with a map with the 6-digit zip codes. For example, data on noise levels were estimated using a noise exposure model, producing noise levels for 100*100 metre grids. Figure 4.1 shows such an overlay. The 'stars' are the 6-digit zip codes, and the squares are the areas with a certain noise level e.g. the noise level in the square in which a certain zip code was situated, was assigned to that zip code. After that, data were read into a statistical software package.

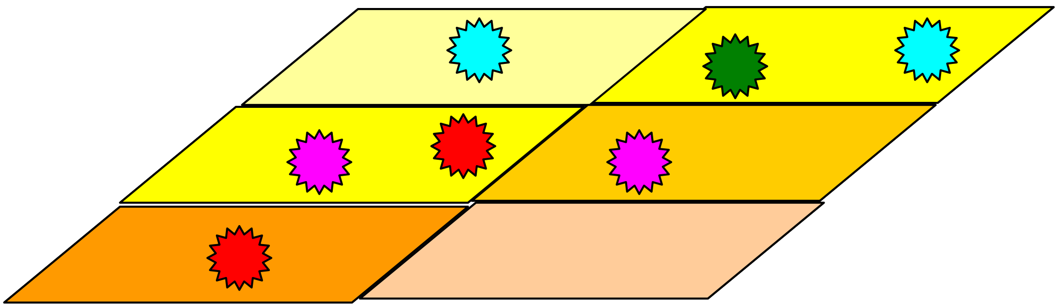

Figure 4.1 Connecting spatial data with 6-digit zip codes

For the statistical analysis we used the statistical software package SAS version 8.2.
Most analyses were performed on the 6-digit zip code level, which was considered as the most important scale level for this study. Some additional analyses have been performed on the 4-digit zip code level for analyses for which relevant data were or could only be made available at that level, such as the analyses on perceived environmental quality. For a general description on the socio-economic distribution of environmental quality (cumulative) frequency tables were produced. The used methods will be explained further in chapters 6, 7, and 8. The results are partly weighted for the number of inhabitants, because in areas with more inhabitants environmental quality has an impact on more people.

5. The spatial distribution of the selected indicators

Figure 5.1 to Figure 5.6 give examples of GIS maps on the spatial distribution of some of the selected indicators.

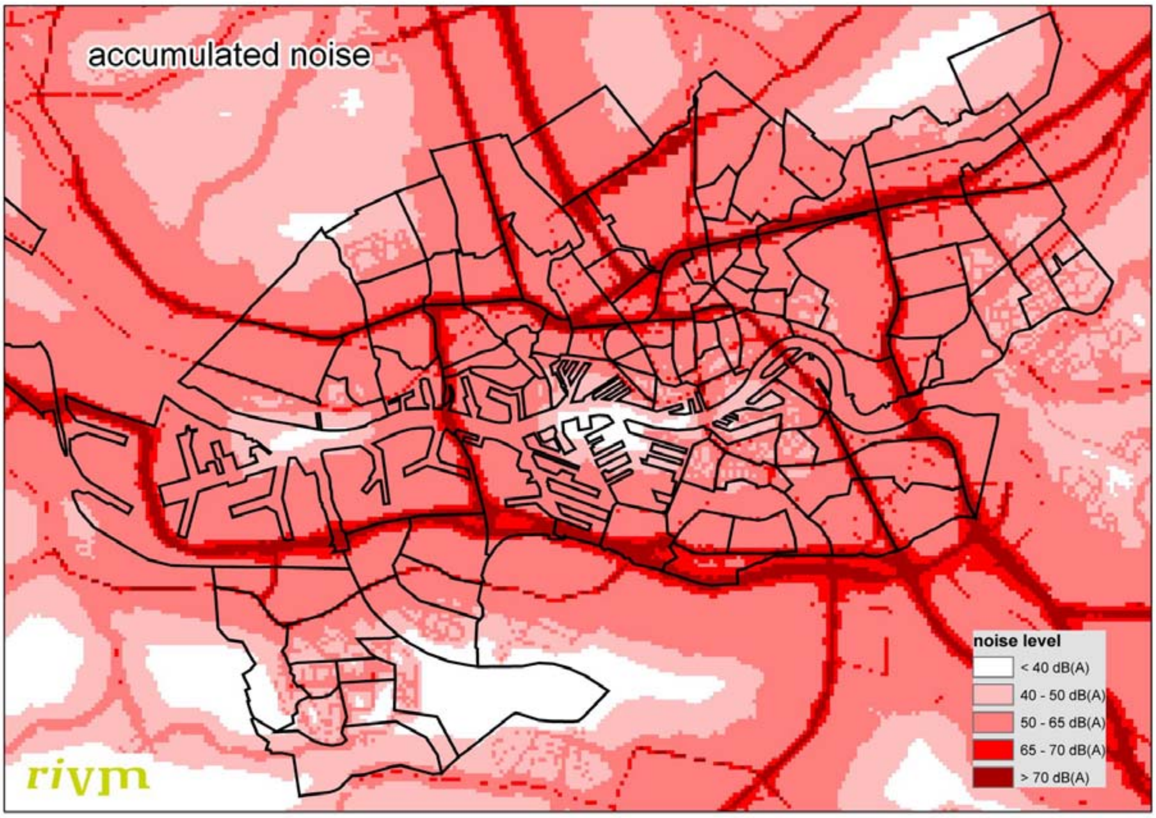

Figure 5.1 Spatial distribution of accumulated noise levels (railroad traffic, aircraft, road traffic) in the Rijnmond region

Logically, Figure 5.1 shows that highest noise levels of road traffic, railroad traffic and aircraft were located nearby their sources (main roads, railroads and Rotterdam airport) crossing many different zip code areas. The same was true for NO_2, an air pollutant directly related to road traffic (Figure 5.2, next page). Availability of public green areas seems to be spread over the whole Rijnmond region (Figure 5.3, next page).

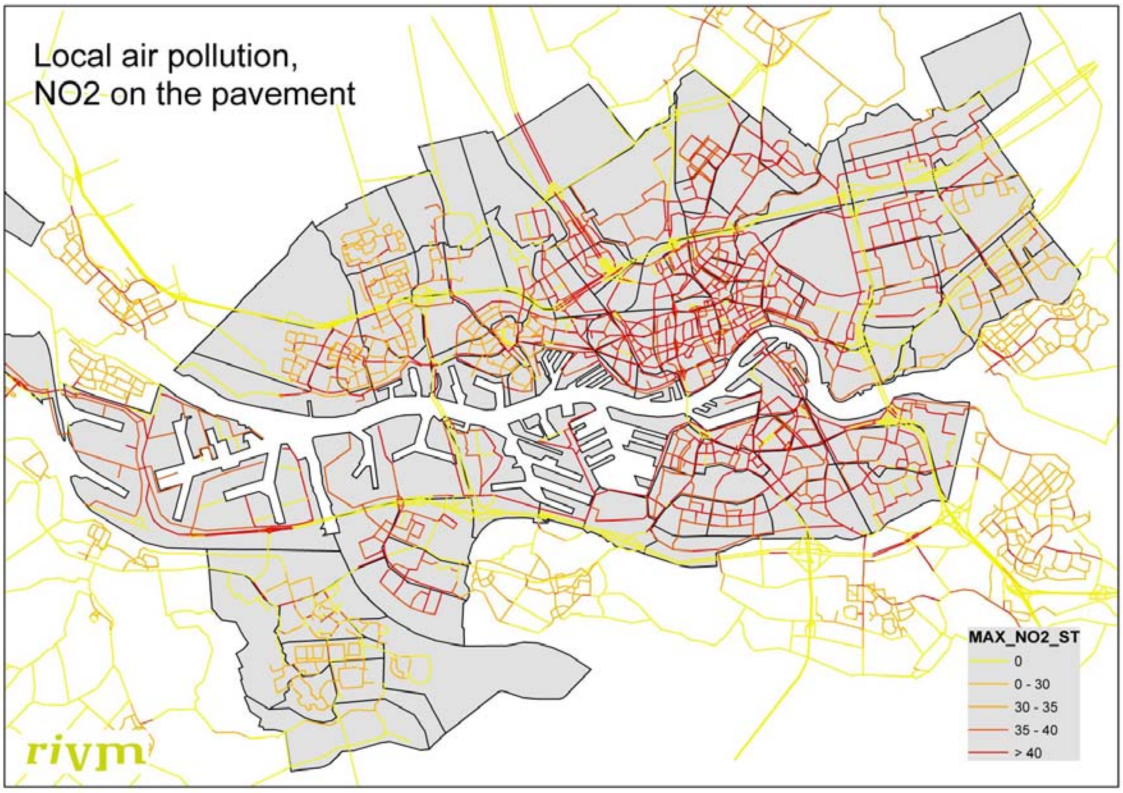

Figure 5.2 Spatial distribution of NO_2 concentrations on the pavement in the Rijnmond region

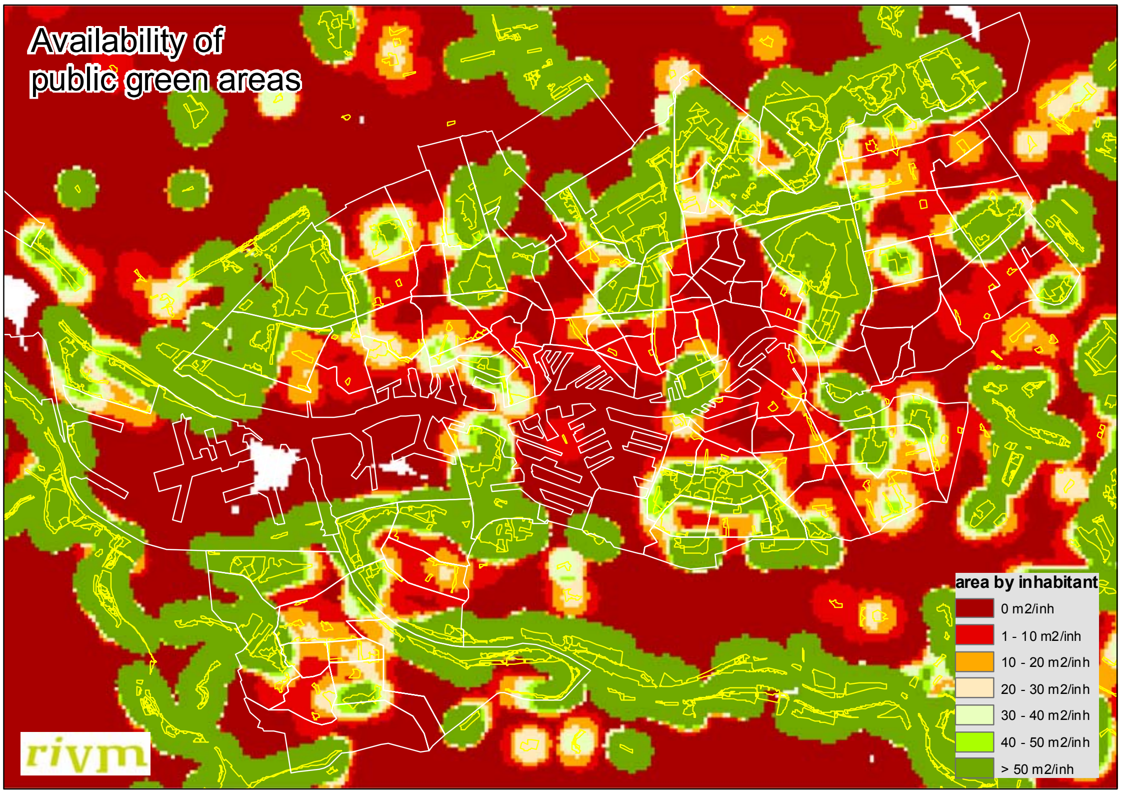

Figure 5.3 Spatial distribution of availability of public green areas (m^2/inhabitant) in the Rijnmond region

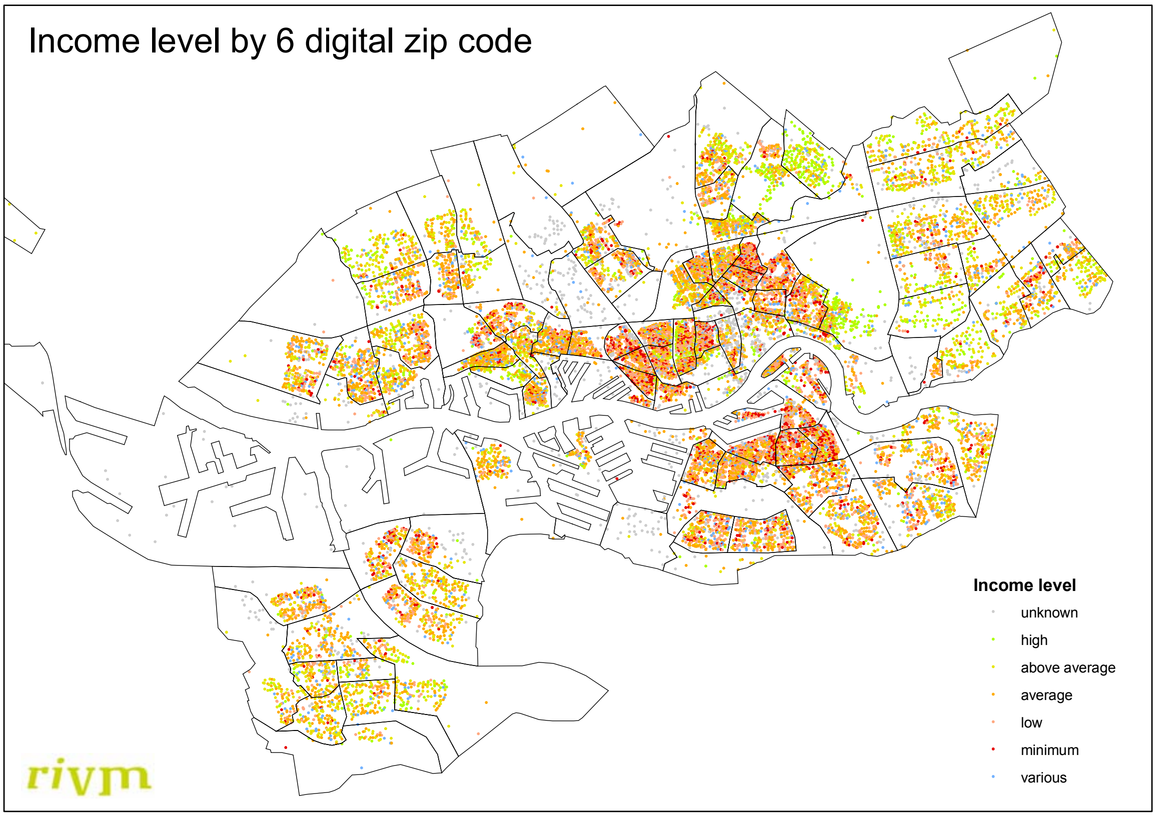

Figure 5.4 Spatial distribution of income categories in the Rijnmond region

Furthermore, the lower income areas seemed to be concentrated in the centre of the Rijnmond region in Rotterdam, but higher-income areas are present there as well (Figure 5.4). Generally, the same spatial pattern was found for the percentage of minorities (Figure 5.5, next page), with a higher percentage of minorities in lower income areas (Nieuwe Westen, Noord, Centrum, Feijenoord, part of Schiedam). The average house price (Figure 5.6, next page) was highest in the northern and southern areas of the Rijnmond region (Spijkenisse, parts of Vlaardingen and Schiedam, Overschie, Hilligersberg-Schiebroek, Prins Alexander, Capelle aan de IJssel, Kralingen-Krooswijk); the highest housing density was found in the centre of the region, in Rotterdam (Centrum, Nieuwe Westen, Noord, Feijenoord, part of Charlois) (see Figure 3.1 for the location of the mentioned boroughs). It should be noted that data on minorities and on house prices were only available at the 4-digit zip code level. Within these areas there might be differences on these indicators that are not shown because of the less detailed spatial scale level compared to e.g. income (available on 6-digit zip code level).

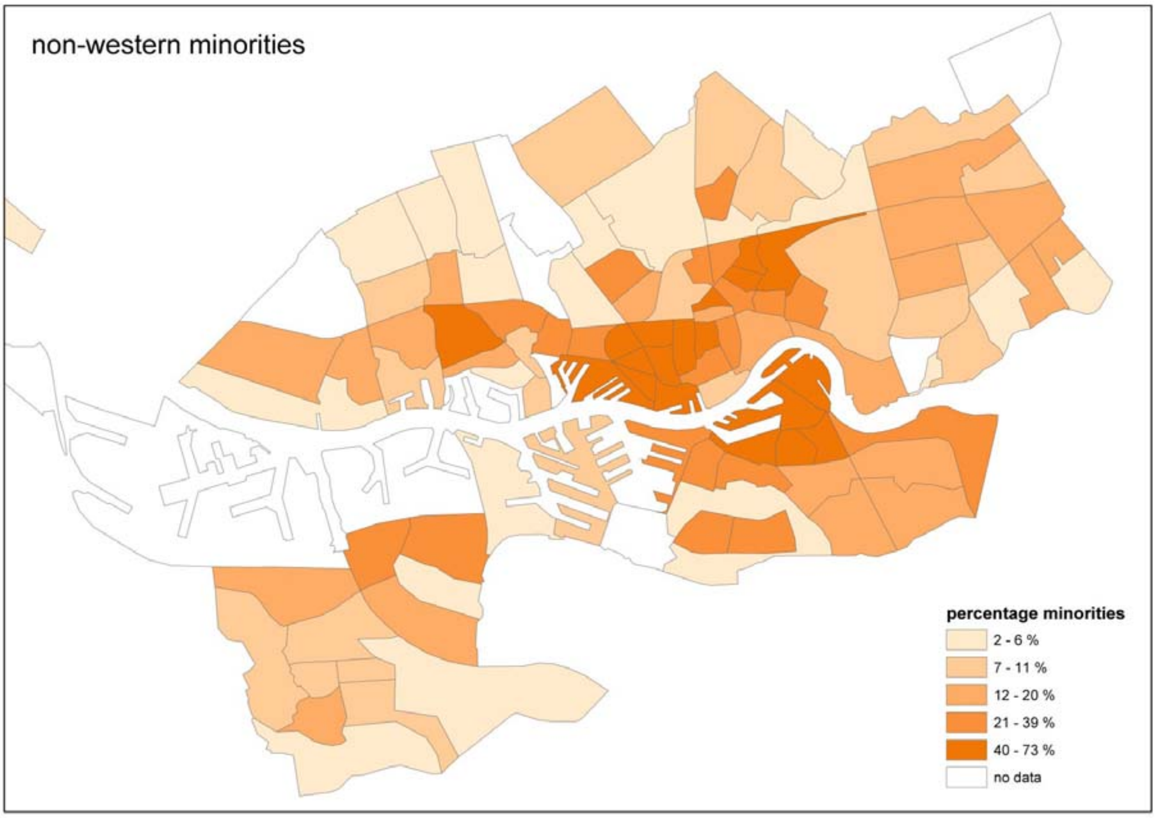

Figure 5.5 Spatial distribution of percentage of non-western minorities in the Rijnmond region

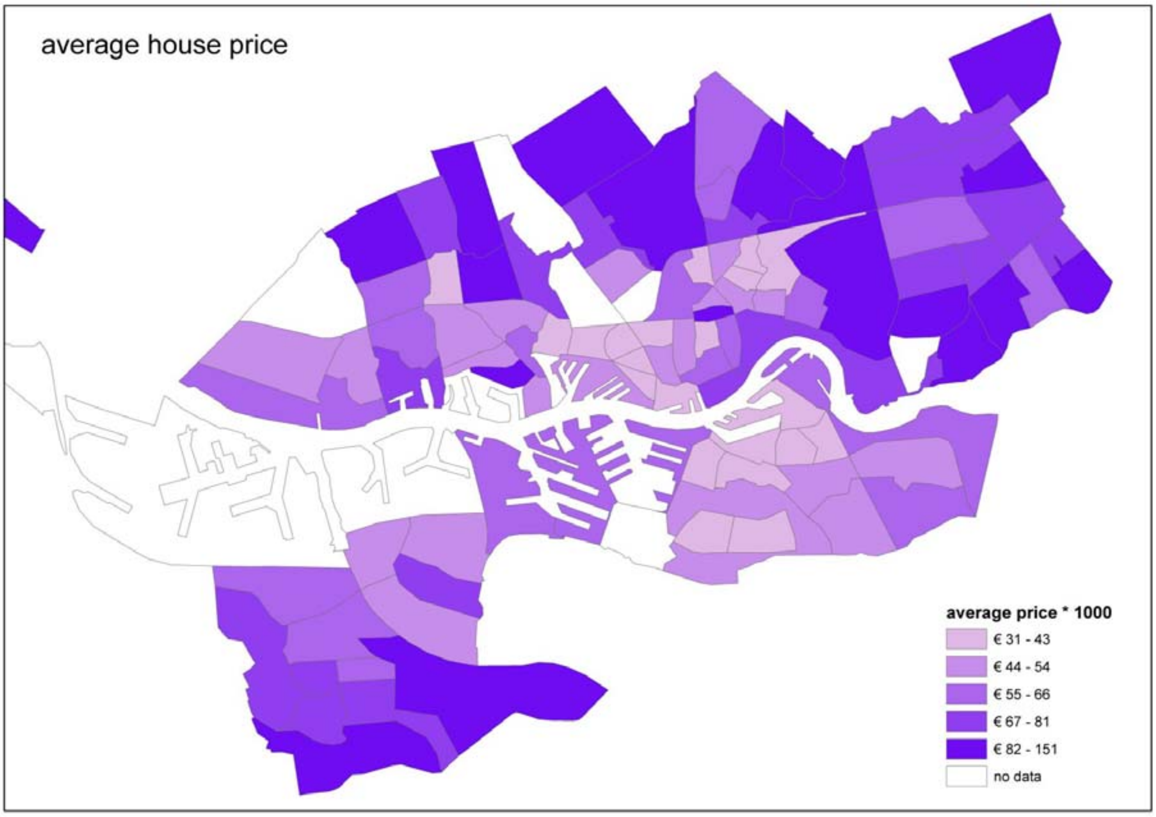

Figure 5.6 Spatial distribution of the average house price in the Rijnmond region

6. The socio-economic distribution of environmental quality

In this chapter the distribution of environmental quality based on 'objective' data is described for different income categories in the Rijnmond region. The first section deals with results on the 6-digit zip code level, presented for each environmental indicator (noise, air pollution, availability of public green areas, dwellings within safety risk contours, presence of waste disposal sites) separately. It starts with a general description of the socio-economic distribution for the specific environmental indicators, followed by a description in terms of 'goods' and 'bads', if possible. These results are weighted for number of inhabitants per 6-digit zip code level unless mentioned otherwise. The second section presents some additional results on the 4-digit zip code level.

6.1 A description of the socio-economic distribution of environmental quality

A. Noise:
The socio-economic distribution of noise is presented in Figure 6.1 (p.33; note that the scales on the x-axis are different for the different graphs). This figure makes clear that differences between income categories are largest for noise from railroad traffic and noise from aircraft, especially at lower noise levels. Considering the mean noise levels per income category, differences were present for all transportation noise sources, but were largest for noise from railroad traffic and noise from aircraft. The average railroad traffic noise level of lowest income category vs. highest income was 47 vs. 41 dB(A), respectively. For aircraft noise, a reversed trend was found, ranging from 19 dB(A) in the lowest income areas to 25 dB(A) in the highest income areas (Appendix 5).
Railroad traffic noise and accumulated noise (noise from railroad traffic, aircraft and road traffic taken together) showed differences between income categories for noise levels above the Dutch standard of 65 dB(A). For railroad noise the percentage of areas with noise levels above this standard ranged from 0.6% of the highest income category areas climbing to 2.6% of the minimum income category areas, and for accumulated noise from 6.0% climbing to 9.3%.
Concerning noise levels below the Dutch target value for noise (50 dB(A)) we found differences for all noise sources, with the highest income category showing the highest percentage of 'quiet' areas, except for aircraft noise, for which the opposite was true. Differences were most pronounced for railroad traffic noise. It appeared that 76.4% of the highest income areas had a noise level below 50 dB(A) compared to 62.5% of the minimum income areas, with the percentage increasing with an increasing income level (Appendix 5).

Differences were present for accumulated noise as well, varying from 7.5% of the minimum income areas to 11.3% of the high income areas having noise levels below 50 dB(A).

B. Air pollution:

In advance one should be aware that there were many 6-digit zip code areas (54%) for which the concentration was modelled to be zero micrograms/cubic metre ($\mu g/m^3$), mainly because NO_2 data were modelled only along roads. For 6-digit areas without a road the concentration was automatically set at zero $\mu g/m^3$. In case all areas including the zero concentration areas were used in the analyses, the differences between income categories were more pronounced than for noise (Figure 6.2, p.34, upper graphs; note that the scales of the x-axes are different for the different graphs). Mean levels of NO_2 at the front of dwellings increased with a decreasing income level, from 12.9 $\mu g/m^3$ for high-income areas, to 21.6 $\mu g/m^3$ for minimum-income areas. For NO_2 on the pavement mean levels ranged from 15.7 to 23.9 $\mu g/m^3$, respectively. The percentage of 6-digit zip code areas with NO_2 levels above the Dutch standard (40 $\mu g/m^3$) at the front of a dwelling was 5.9% for the highest income areas, increasing to 20.6% for minimum income areas (Appendix 6). For NO_2 levels on the pavement this was 17.6% for the highest income areas, increasing to 36.5% for minimum income areas.

When the areas with a zero concentration were left out of the analyses differences were smaller. Average concentrations for NO_2 on the pavement varied from 38.8 $\mu g/m^3$ for the above average income category to 41.9 $\mu g/m^3$ for the minimum income category (Figure 6.2, p.34, lower graphs; Appendix 6). Not the high-income areas, but the above average income areas had the lowest concentrations in this case. Furthermore, 38.4% of the 6-digit zip code areas of the above average income category climbing to 64.0% of the minimum income category had NO_2 levels on the pavement above the Dutch standard (40 $\mu g/m^3$). For NO_2 levels at the front of a dwelling, the concentrations varied from 35.6 $\mu g/m^3$ in high-income areas to 38.9 $\mu g/m^3$ for the minimum-income category. The percentage of areas with levels above the Dutch standard in that case for the minimum income category more than twice the percentage for the high-income category (37.1% vs. 16.3%) (Appendix 6).

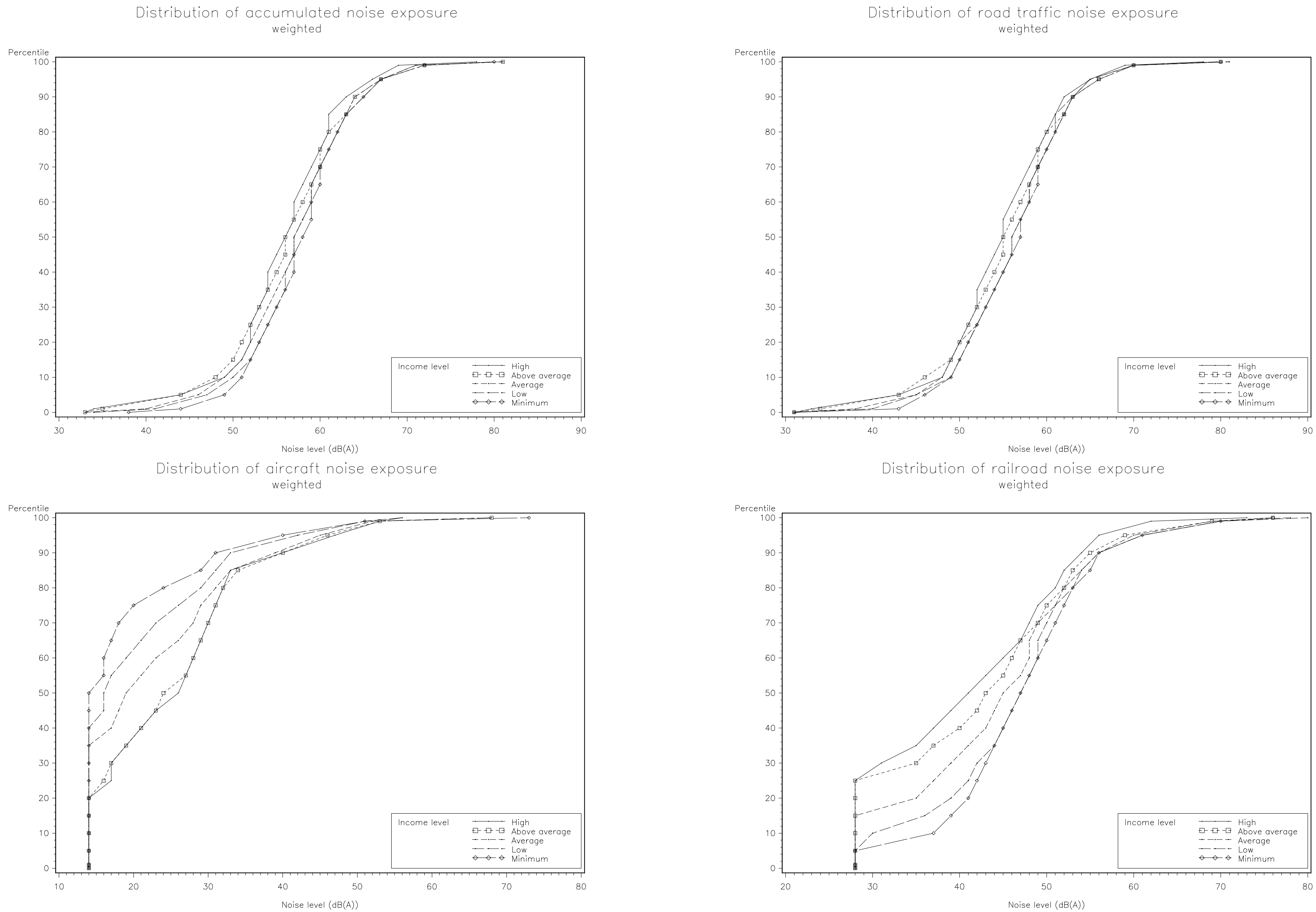

Figure 6.1 Distribution of noise exposure by income level

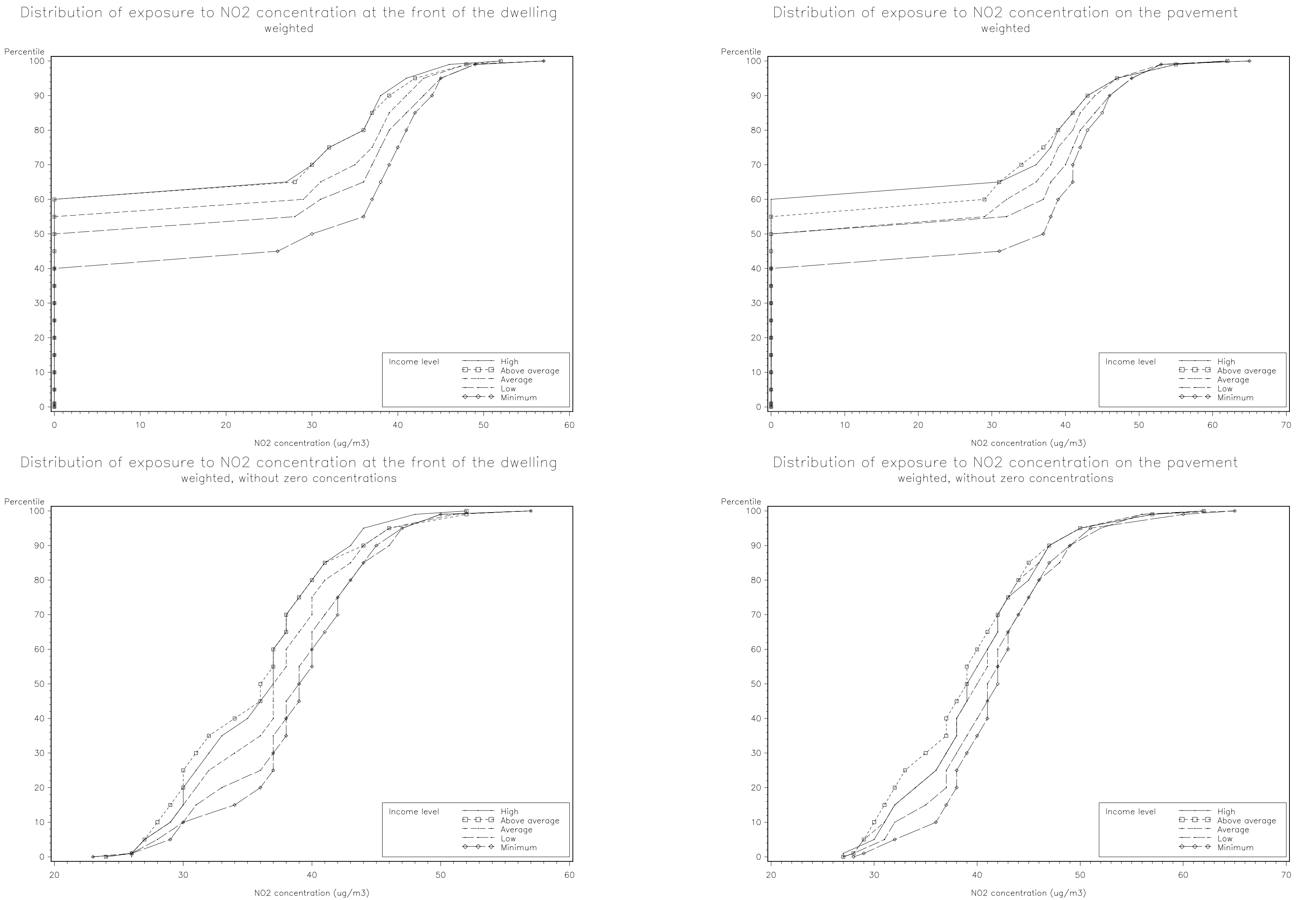

Figure 6.2 Distribution of exposure to NO_2 by income level

C. Availability of public green areas:
Table 6.1A shows that in higher income areas the average amount of available public green areas (square meters of parks, forests, recreational areas, the number of people with whom one has to share it) is higher than in lower income areas.

Table 6.1 A. Average amount of public green areas (m^2) available per inhabitant for various income categories (weighted)

Income category	Distance 200 metres (m) AM (sd)[a]	Distance 500 m AM (sd)	Distance 1000 m AM (sd)
High	**43 (2230)**	**61 (3394)**	**61 (1615)**
Above average	**25 (1500)**	**31 (2585)**	**41 (3106)**
Average	**17 (939)**	**23 (1243)**	**27 (726)**
Low	**12 (587)**	**17 (1262)**	**22(1106)**
Minimum	**11 (1077)**	**16 (1889)**	**18 (198)**
Various	17 (396)	26 (480)	31 (622)
Unknown	29 (70)	31 (337)	25 (67)

[a] AM: arithmetic mean; sd: standard deviation

The amount of available public green areas in the highest income areas was 61 m^2 per inhabitant compared to 16 m^2 per inhabitant in minimum income areas, within a distance of 500 m. 77.8% of the highest income areas did not have 50 m^2 within 500 metres distance ('standard' for public green areas based on expert judgement). This percentage increased with decreasing income level towards 92.6% of the minimum income areas (Appendix 7).

D. Percentage of dwellings within a safety risk contour:
No clear trend for income was found for this indicator (Table 6.1B). However, Table 6.1B shows that in the highest income areas the percentage was more than three times smaller than in the other areas (1% vs. about 4% respectively).

Table 6.1 B. Average percentage of dwellings within a safety risk contour for various income categories (weighted)

Income category	Average percentage of dwellings within safety contour
High	**1.0**
Above average	**3.8**
Average	**4.2**
Low	**3.7**
Minimum	**3.7**
Various	4.3
Unknown	0.4

E. Presence of waste disposal sites:
Table 6.1 C presents percentages of 6-digit zip code areas with waste disposal sites per income category. It shows that the lower the income, the higher the chance to have a waste disposal site in the surroundings of the dwelling, at least at distances of 500 and 1000 metres. No clear trend was found within 250 metres. Only a very small percentage of areas had a waste disposal site within 250 metres.

Table 6.1C. Percentage of zip code areas with a waste disposal site within a certain distance for different income categories (weighted)

Income category	Distance 250 m	Distance 500 m	Distance 1000 m
High	**0**	**0.5**	**2.5**
Above average	**0**	**0.6**	**4.7**
Average	**0.3**	**1.5**	**6.9**
Low	**0.3**	**1.4**	**7.5**
Minimum	**0.2**	**2.2**	**7.7**
Various	0	0.9	6.7
Unknown	0	0	3.2

6.2 Additional results from analyses at the 4-digit zip code level

We performed additional analyses at the 4-digit zip code level with data on socio-economic indicators being available only on that spatial scale level.

Income
To be able to perform analyses on the 4-digit zip code level environmental data on all 6-digit areas within a 4-digit zip code level were averaged. The way in which income data were available at the 4-digit zip code level did not offer a direct possibility to perform descriptive analyses as performed on the 6-digit zip code area. Furthermore, it was not possible to aggregate the income indicator available on the 6-digit zip code level to the 4-digit zip code level, so we could not compare income data from different spatial scale levels directly. Because it was not clear from theories or experience what indicator was best, the four different definitions for income (average income per inhabitant, average income per income recipient, percentage of people of a certain income category, percentage of people with a certain income level; see Appendix 1B) were all used in the analyses. It was not possible to perform descriptive analyses, so instead we performed univariate regression analyses to get some insight in the relation between the environmental indicators and income. These results are not weighted for number of inhabitants per 4-digit zip code area. Weighing, used to adjust for the fact that in areas with more inhabitants the environmental quality present has an impact on more people, does not influence the results in these univariate regression analyses, and was therefore not necessary. Appendix 8 shows the unweighted results of the univariate

analyses. The income indicators for which the R^2 and p-value are bold have the strongest relation with a certain environmental indicator.
For *noise* the extent to which differences in noise levels were explained by income depended on what definition was used. If the percentage of people within a certain income category was used as the definition of the income indicator, there was a statistically significant ($p<0.05$) relation between differences in noise levels (all separate sources and accumulated) and income. However, if data on the average income per inhabitant was used, this relation was not statistically significant, except for aircraft noise. Again we found that the higher the income level, the higher the noise exposure, except for aircraft noise, for which agasin the opposite was true.
For *air pollution*, the negative relation between air pollution levels and income was statistically significant for all definitions of income, except for income defined as 'average income per inhabitant'.
For *availability of public green areas*, it was not clear what income indicator explained most of the differences in the amount of available public green areas, but in most occasions the relation was statistically significant.The higher the income, the higher the amount of public green areas being available per inhabitant.
The *percentage of dwellings within a safety risk contour* did not show a statistically significant relation with income, independent of the definition of the income indicator.
For *presence of a waste disposal site* within a certain distance did not show statistically significant results either. The association was strongest with the percentage of people of a certain income category at all distances.

Overall, the definition of income with categories instead of continuous data appeared to explain more of the differences in environmental quality between areas, especially when income was defined as the percentage of people of a certain income category (<30, 30-50, 50-80, >80,000 guilders/year).

Non-western minorities

Other analyses performed at the 4-digit zip code level concerned the influence of the presence of non-western minorities. This indicator has been used in many American studies on environmental justice, instead of or together with income. In those studies it is often questioned if it is either income or ethnicity that makes the difference in environmental quality. In the Rijnmond region this is difficult to find out, because income and the percentage of non-western minorities are fairly strong correlated with each other (correlation coefficient of about 0.7; see Appendix 2), which might result in co-linearity. Appendix 9 shows results of the regression analyses. Significant associations for the association between the percentage of non-western minorities and environmental quality were found for noise from railroad traffic, aircraft noise, air pollution, and availability of public green areas within 500 and 1000 metres, but not for the other environmental indicators. The higher the percentage of non-western minorities, the worse the environmental quality concerning these indicators.The associations were strongest for aircraft noise and air pollution, in which 25%

of the variance was explained by the percentage of non-western minorities in a zip code area. The percentage of non-western minorities also influenced the association between income and environmental quality.

6.3 Summary of the results

In general, inhabitants of higher income areas appeared to have more access to environmental ‘goods’ than inhabitants of lower income areas. Furthermore, environmental ‘bads’ were more often present in lower-income areas than in higher-income areas. On the 6-digit zip code level, these differences showed especially for air pollution (the higher the income, the lower the levels of NO_2), availability of public green areas (the higher the income, the higher the amount of availability of public green areas), and for presence of a waste disposal site in the surroundings (the higher the income, the lower the chance of having a waste disposal site in the surroundings). For noise, differences were larger for noise levels below 50 dB(A) compared with noise levels above 65 dB(A), and most pronounced for noise from railroad traffic and accumulated noise. A decrease in income level corresponded with a decreasing percentage of areas with a noise level below 50 dB(A). An exception was found for aircraft noise, for which the opposite was true. For percentage of dwellings within a safety contour, only the highest income category showed to have a lower percentage of dwellings within the safety contour compared to the other income categories.
On the 4-digit zip code level, the association between income and the aforementioned environmental indicators was generally confirmed, with again the strongest relation between air pollution (NO_2 levels) and income (negative association), and no clear relation between percentage of dwellings within a safety risk contour and income. The definition used for income influenced the results found on this scale level, and the percentage of people of a certain income category (< 30, 30-50, 50-80, > 80,000 guilders/year) explained more of the differences in environmental quality between areas in most cases than the income indicators defined in another way. In addition, the percentage of non-western minorities, being highly correlated with income level, was related to local environmental quality as well, especially for aircraft noise and NO_2, but also for availability of public green areas. The percentage of non-western minorities seemed to influence the association between income and environmental quality as well. This might indicate that the presence of non-western minorities is an influential socio-economic indicator, next to income.

7. Accumulation of 'bads' and 'goods' and its socio-economic distribution

In the previous chapters we considered the socio-economic distribution for various environmental quality separately. However, people are often exposed to more than one impact (either 'good' or 'bad') at the same time in their local surroundings ('hot spots'). Therefore, we analysed the accumulation of quality in each 6-digit zip code area for both the accumulation of 'bads' and the accumulation of 'goods'. Based on that information policy makers could e.g. determine in what areas measures are needed most urgently.
There are several ways to investigate the accumulation of 'goods' and 'bads' and to define 'goods' or 'bads', dependent on the perspective used in and aim of a study. One could for example look at the extent to which the levels for a certain indicator divide from the average level in the community or the average national level, counting the number of problems occurring in a neighbourhood, or one can take the perception of inhabitants, the ranking in importance of indicators, as a starting point. In this case study three levels of accumulation were defined for both environmental 'bads' and for environmental 'goods', connecting to the perspective presented in Table 2.2. They also might give some insight in the spectrum of 'minimum quality' to a 'nice and pleasant' local environment, as mentioned in chapter 2.
The first level of accumulation was defined based on existing Dutch and European standards for noise and air pollution and might be considered as an indication of a minimum quality environment. The second level included presence of dwellings within a safety contour as well, because this is related (next to noise and air pollution) to health and safety of people, which are often considered as basic issues for which inhabitants should be protected. This is the middle category in the spectrum. The third level is again one step further, including also availability of public green areas, using a standard mentioned by Dutch experts not being implemented in law, and presence of waste disposal sites within a certain distance. These last issues may be considered as 'extra' issues, making the local environment nicer and more pleasant for inhabitants, but are not as basic as the issues included in the first two levels.
These levels of accumulation are presented in Table 7.1, and explained further below.

<u>'bads':</u>

level 1: An accumulated noise level (road traffic, aircraft and railroad traffic) of more than 65 dB(A) and an NO_2 level on the pavement of more than 40 $\mu g/m^3$;

level 2: An accumulated noise level of more than 65 dB(A), an NO_2 level on the pavement of more than 40 $\mu g/m^3$, and dwellings within a safety contour;

level 3: An accumulated noise level of more than 65 dB(A), an NO_2 level on the pavement of more than 40 $\mu g/m^3$, dwellings within a safety contour, less than 50 m^2 available public green areas within a distance of 500 metres, and presence of a waste disposal site within 250 metres.

<u>'goods':</u>

level 1: An accumulated noise level of less than 50 dB(A) and an NO_2 level on the pavement of less than 40 µg/m^3;

level 2: An accumulated noise level of less than 50 dB(A), an NO_2 level on the pavement of less than 40 µg/m^3, and no dwellings within a safety contour;

level 3: An accumulated noise level of less than 50 dB(A), an NO_2 level on the pavement of less than 40 µg/m^3, no dwellings within a safety contour, more than 50 m^2 available public green areas within a distance of 500 m, and no waste disposal site present within 1000 m.

Table 7.1 Accumulation of environmental indicators: definition of levels

	'Bads'			**'Goods'**		
	Level 1	***Level 2***	***Level 3***	***Level 1***	***Level 2***	***Level 3***
Accumulated noise	+ > 65 dB(A)	+	+	+ < 50 dB(A)	+	+
NO_2	+ > 40 µg/m^3	+	+	+ < 40 µg/m^3	+	+
Safety risks	-	+ dwellings within a contour	+	-	+ no dwellings within a contour	+
Availability of public green areas	-	-	+ < 50 m^2 within 500 m	-	-	+ > 50 m^2 within 500 m
Presence of waste disposal sites	-	-	+ waste disposal site within 250 m	-	-	+ no waste disposal site within 1000 m

+ included; - not included

We analysed the socio-economic distribution of accumulations of 'goods' and 'bads', resulting in the distribution presented in Table 7.2. This table shows that the percentage of areas with accumulation of the 'bads' is not so large (about 3% for level 1, and 0% for level 2 and level 3). Considering the distribution of 'bads' among income categories, there was no clear trend, except that a higher percentage of minimum-income areas had an accumulation of noise and air pollution problems compared to the other areas. The differences in accumulation of 'goods' (Table 7.2), however, appeared to be larger. These results indicate that the higher the income level, the higher the percentage with accumulation of environmental 'goods' in the local surroundings. A subdivision between average to high-income areas and low and minimum-income areas seems to be present.

Table 7.2 Percentage of zip code areas with accumulation of 'bads' or 'goods' for different income categories (weighted)

Accumulation of environmental 'bads':

Income category	**Accumulation of 'bads'** ***Level 1***
High	**3.0**
Above average	**2.8**
Average	**2.9**
Low	**3.6**
Minimum	**5.3**
Various	3.9
Unknown	1.9
Overall	3.3

Accumulation of environmental 'goods':

Income category	**Accumulation of 'goods'** ***Level 1***	**Accumulation of 'goods'** ***Level 2***	**Accumulation of 'goods'** ***Level 3***
High	**11.2**	**11.3**	**3.3**
Above average	**13.0**	**12.9**	**2.5**
Average	**11.2**	**11.1**	**1.0**
Low	**7.7**	**7.5**	**0.2**
Minimum	**5.9**	**6.2**	**0.2**
Various	9.9	9.3	1.7
Unknown	5.4	9.3	0
Overall	10.2	10.1	1.2

Furthermore, we looked at the spatial distribution of accumulation of 'bads' and 'goods'. Generally, accumulation of these 'bads' was present in the centre of the Rijnmond region, in the city of Rotterdam (Figure 7.1). Accumulation of 'goods' showed to be concentrated at the northern and southern borders of the Rijnmond Region (Figure 7.2-7.4, next pages). Amidst areas with accumulation of 'bads', there were also some 4-digit zip code areas in the central part, in which accumulation of environmental 'goods' was present.

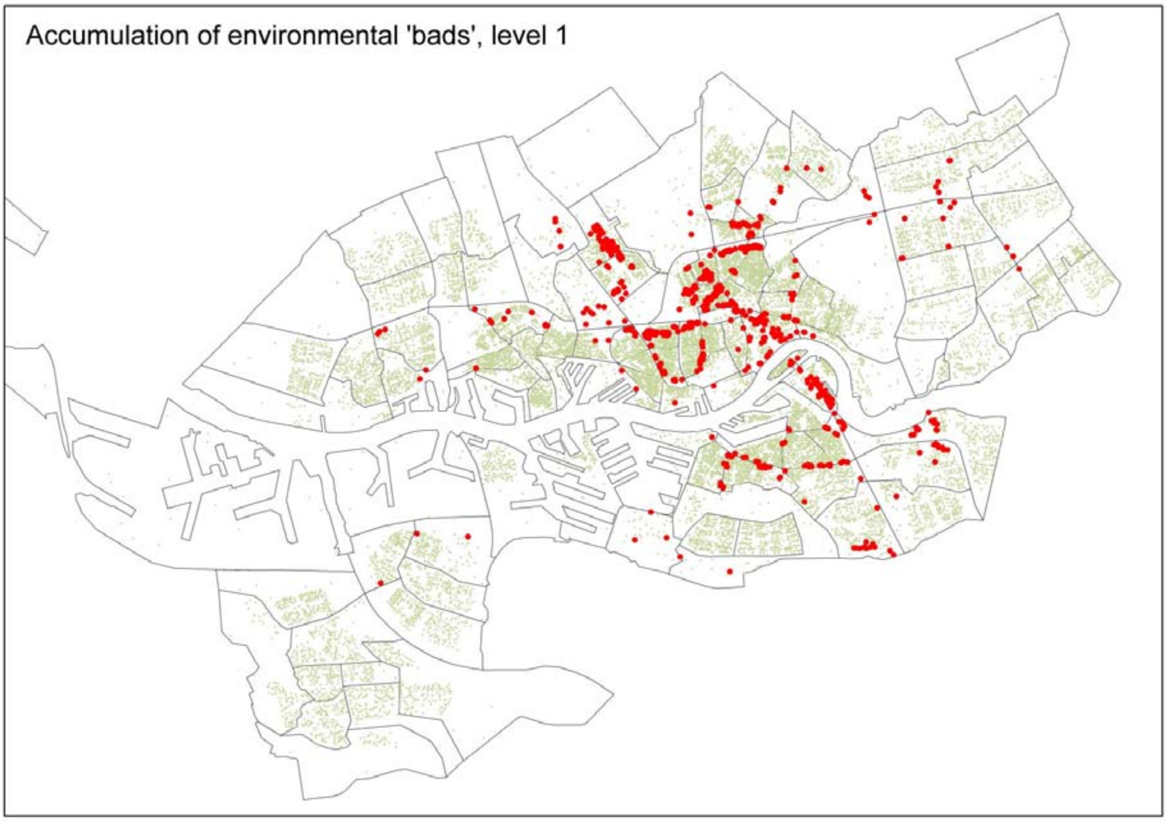

Figure 7.1 Spatial distribution of accumulation of environmental 'bads', level 1

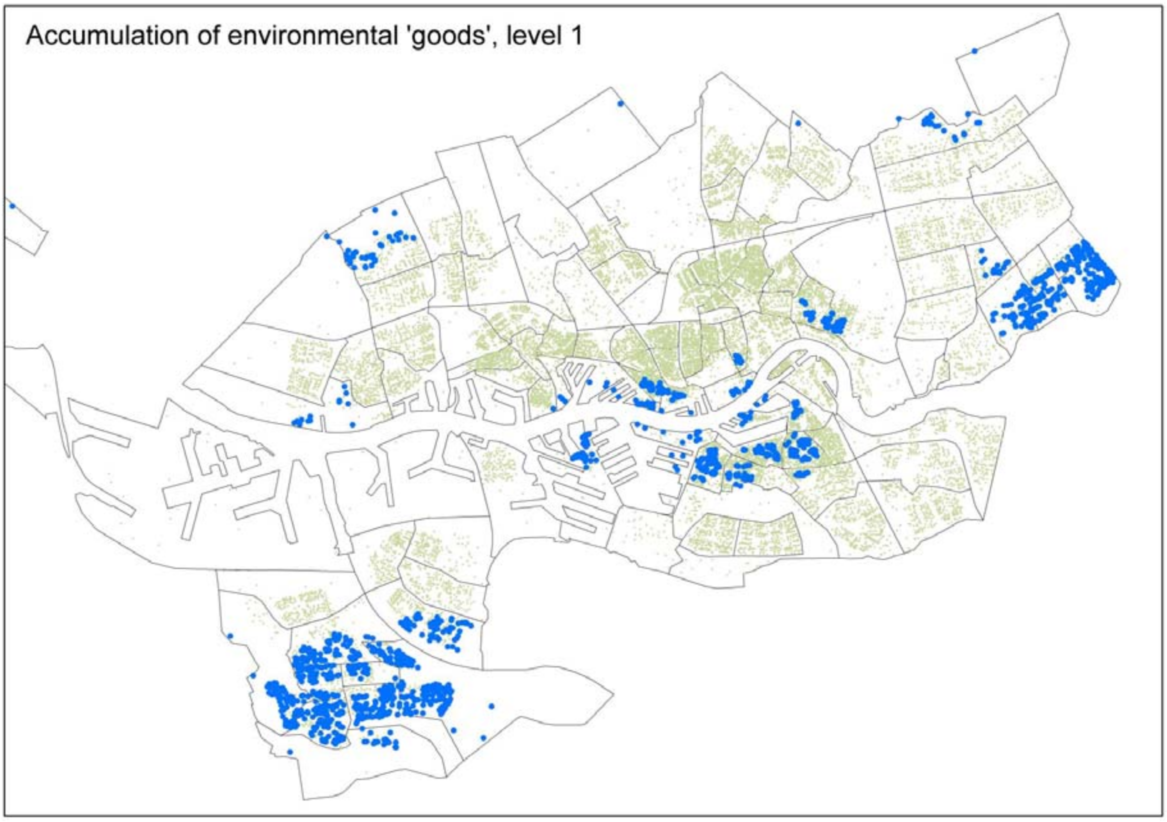

Figure 7.2 Spatial distribution of accumulation of environmental 'goods', level 1

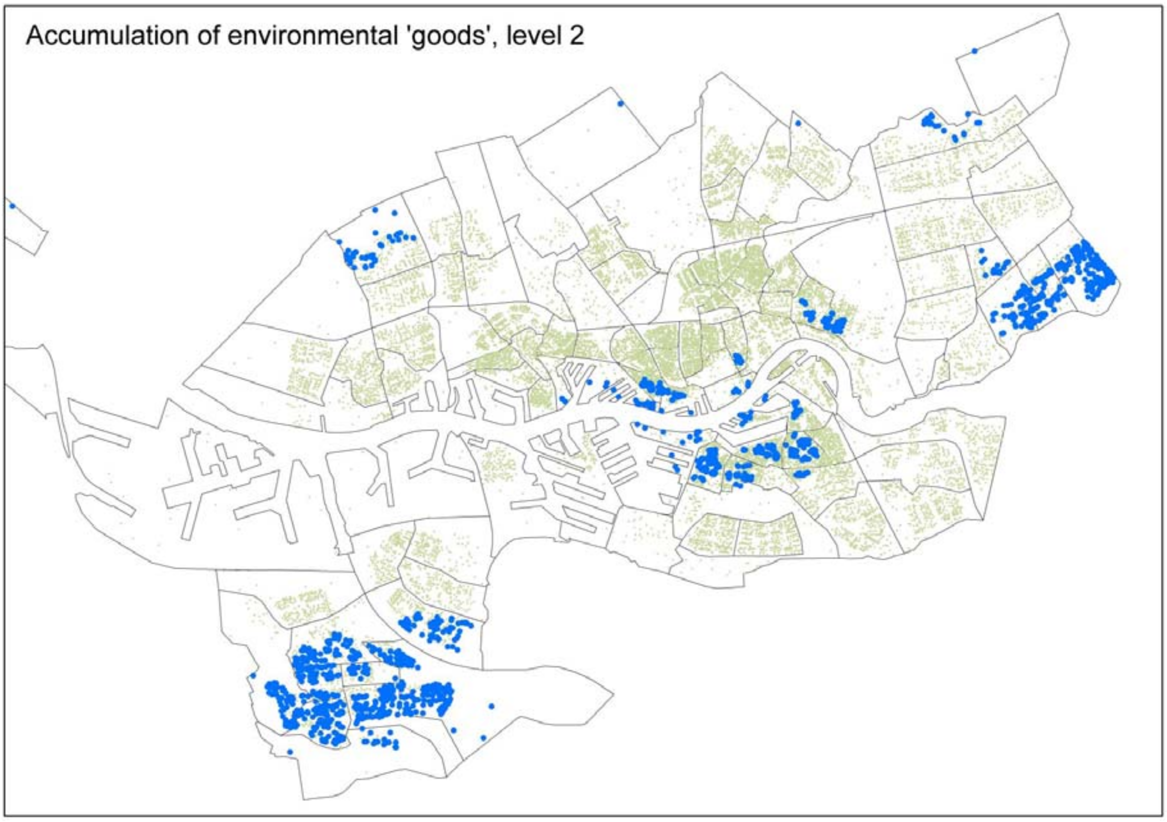

Figure 7.3 Spatial distribution of accumulation of environmental 'goods', level 2

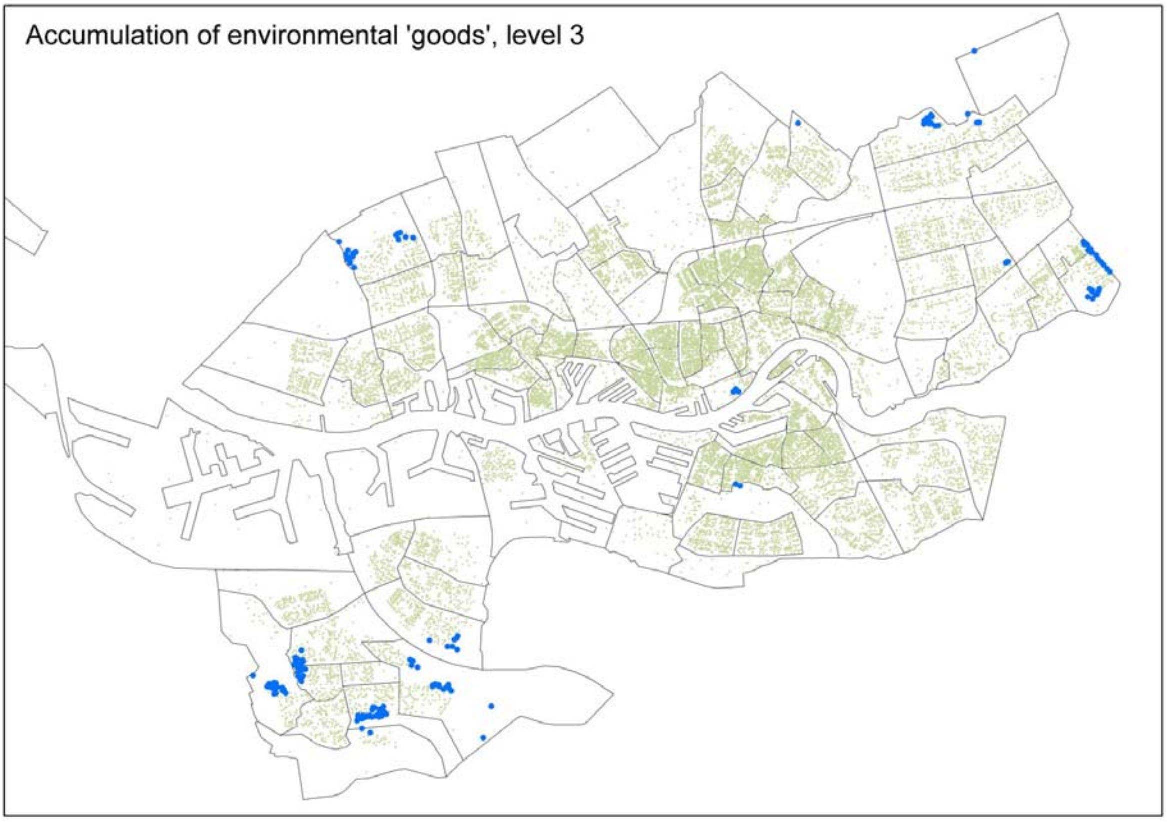

Figure 7.4 Spatial distribution of accumulation of environmental 'goods', level 3

8. Perceived environmental quality in the Rijnmond region

So far, we only used the so-called ‘objective’ indicators to describe the socio-economic distribution of environmental quality. However, as mentioned in chapter 2, perception of the inhabitants concerning environmental quality in their neighbourhood is relevant as well to get a full insight in the socio-economic distribution of local environmental quality. Perception of people can be considered as the result of the expectations concerning their local environment (‘needs’) and the real situation. For example, if people expect to live in a neighbourhood with a lot of public green areas, and these areas are not available in their neighbourhood, this may result in dissatisfaction about the availability of public green areas in their neighbourhood. This depends not only on the present environmental quality, but also on personal and contextual aspects (Van Kamp *et al.*, 2003).
In this chapter we focus on four aspects. First, we pay attention to the perception of inhabitants of the Rijnmond region in general, and in comparison with the Netherlands. Second, we focus on spatial differences in perception within the Rijnmond region. Third, we describe socio-economic differences in the way inhabitants perceive environmental quality in their neighbourhood. Fourth, we explore the association between ‘objective’ and perceived environmental quality in the Rijnmond region. This will give an idea of differences in perception of the quality of the local environment and environmental quality based on ‘objective’ measures.

8.1 Data sources and methods of analysis

In order to describe the socio-economic characteristics of perceived environmental quality we used two types of data. In the first place we used data from regional or local research presented in literature. Note that data were available from different surveys performed in different years. In the second place we used the ‘objective’ data on environmental quality and income already described in previous chapters, combined with the interview data from the local statistical agency of the city of Rotterdam, collected between 1997 and 1999 in Rotterdam. Data on perception of inhabitants were available on the level of boroughs, while data on environmental indicators were available on the 6-digit level. We merged the data on the 4-digit zip code level by using the interview data of the borough for all 4-digit zip code areas within the borough, and used the aggregated environmental data. In some boroughs less than 50 people were interviewed, resulting in unreliable results. Therefore, the results of these analyses should be interpreted carefully. We performed simple correlation analyses (Spearman method).

8.2 Perceived environmental quality in the Rijnmond region- a general description

In 1998 the Province of South-Holland performed a survey on the perception of inhabitants on environmental quality in their direct surroundings in several neighbourhoods near a harbour or industry, but also among a representative sample of inhabitants in the Rijnmond region. This survey showed that 12% of the Rijnmond population was dissatisfied with the environmental situation in their neighbourhood. In the areas near a harbour or industry this percentage was around 16%. Annoyance due to traffic appeared to be the main unpleasant aspect of living in that neighbourhood, mentioned by 14% of the respondents. At the same time the quietness of the neighbourhood was mentioned to be the most pleasant aspect of living in that neighbourhood by 28% of the inhabitants. Environmental issues in the neighbourhood thus seemed to play an important role for residents in the Rijnmond region initially. However, when asking to what problems in society the government should pay attention, environmental management was only fourth in rank, after health care, security of citizens, and employment opportunities. Before 1990 inhabitants ranked it relatively higher. Furthermore, more people were dissatisfied with space in the streets, public transport and the situation in the streets than with the environmental situation (Table 8.1) (Kamphuis, 1998).

Table 8.1 Percentage of inhabitants dissatisfied with an aspect of their local environment in the Rijnmond region, 1998.

Dissatisfied with:	*Rijnmond -North*[1]	*Rijnmond -South*[1]	*Reference Areas*
Dwelling	11	8	4
Situation in the streets	20	23	17
Space in the streets	22	22	17
People in the neighbourhood	8	10	4
Environmental situation	17	16	3
Facilities in the neighbourhood	11	17	6
Parks etc. in the surroundings	8	9	8
Public transport	21	17	40
Living situation in general	3	5	1

[1] *neighbourhoods near a harbour or industry*

Source: Province of South-Holland, 1998

In addition, satisfaction with the local environment was mainly determined by the extent of satisfaction with the dwelling, followed at distance by the situation in the streets, satisfaction with neighbours and with facilities in the neighbourhood in Rotterdam. The environmental situation and satisfaction with parks showed a much weaker, but significant association with the general satisfaction with the local environmental (Bik, 1999). Nevertheless it was the second issue mentioned to be a problem in Rotterdam by 29% of the participants, after social security (70%) (Luijkx and Rijpma, 2001). In 1990, 39% of the inhabitants of Rotterdam

mentioned environmental problems to be one of the three most important problems in the city, decreasing to 15% in 1996, but this increased again to 29% in 2001 (Woudenberg and Elsman, 1998; Luijkx and Rijpma, 2001). Thus, although the inhabitants of this region think there are environmental problems in their direct surroundings, it is generally not the most important aspect in their judgement on their living conditions and in society. This is comparable to results found in other studies (among others Van Kamp *et al*., 2003). From surveys performed in the city of Rotterdam it appeared that inhabitants of this region were and still are less satisfied with their local environment than in the Netherlands as a whole. Furthermore, their inclination to move was higher than in the Netherlands in general. Their consciousness of the environment was less compared to other Dutch people before 1992, but became equal or more in the years after. Although they had a lesser feeling to be able to influence the decision-making processes compared to the general Dutch population, the inhabitants of the Rijnmond region appeared and still appear to be good in moderating environmental problems (Openbaar Lichaam Rijnmond in: Woudenberg and Elsman, 1998). The general opinion of inhabitants of the Rijnmond region on environmental quality has become slightly more positive since 1990. It was influenced mainly by annoyance due to air pollution. In 1990 17% of the inhabitants living close to the harbour and industries of the Rijnmond region said that the environmental quality had (slightly) improved, increasing to 21% in 1996. In addition, more inhabitants of these areas evaluated environmental quality to be (highly) acceptable (50% in 1990 increasing to 70% in 1996) (Woudenberg and Elsman, 1998). At the same time the percentage of inhabitants annoyed by air pollution decreased, just like the air pollution concentrations of SO_2 and Pb. However, other traffic related air pollutants did not show an improvement (Woudenberg and Elsman, 1998).
It should be noted that people defined ‘environment’ very broadly, including littering and dog mess as well. In 2001 respondents from a survey in Rotterdam mentioned littering and dog mess most often to be the largest environmental problem (42%), followed by damage to green areas (14%), air pollution (12%), risks by industrial companies (10%) and noise annoyance (9%). Environmental exposure due to traffic (6%), water pollution (5%), malodour (4%) and soil pollution (3%) were mentioned by a fairly smaller percentage (Luijkx and Rijpma, 2001). Table 8.2 shows the percentages of annoyed people in 1998 for different environmental indicators. In this survey traffic noise is mentioned to be the largest source of annoyance.

Table 8.2 Percentage of annoyed or worried inhabitants related to environmental aspects in their local environment, Rijnmond region, 1998

Source of annoyance	*% of annoyed inhabitants*
Malodour from industry	23
Malodour from traffic	24
Traffic noise	43
Industrial noise	12
Air traffic noise	26
Dust from industry	31
Worries due to presence of hazardous industry	13

Source: Province of South-Holland, MBO 1998

8.3 The spatial distribution on perceived environmental quality in the Rijnmond region

Based on a survey on the living situation in Rotterdam, spatial differences in the appreciation of the living situation appeared to be present. Inhabitants from Hoek van Holland, Hillegersberg-Schiebroek and Prins Alexander were more satisfied; inhabitants from Delfshaven, Feijenoord and Charlois (see Figure 3.1) were less satisfied, and inhabitants from the other boroughs were neutral in the appraisal of their living situation, compared to the city's average appraisal (Bik, 1999).
Based on a sustainability survey from the local statistical agency of Rotterdam (COS) four areas were defined, namely the city centre, the north-western part, the north-eastern part, and the southern part. Participants living in the city centre of Rotterdam more often mentioned environmental problems (most often specified as pollution in general) to be one of the most important problems than the other participants, and people living in the southern part mentioned it least often. Participants living in the city centre more often defined environmental problems as general pollution than the other participants. In Table 8.3 it is indicated from what part of Rotterdam most participants mentioned a certain environmental problem. The report also presented opinions of the participants on the amount of public green areas (parks, recreational areas, and nature) in Rotterdam and its surroundings. Participants living in the city centre most often reported a shortage in the amount of green areas. These people showed a special interest in city parks, just like participants living in the south. In the north-western part people prefer an open pasture (Luijkx and Rijpma, 2001).

Table 8.3 Overview of areas of Rotterdam mentioning a certain environmental problem most often

Environmental problem	*Most often mentioned in*
Littering and dog mess	City centre
Noise annoyance	City centre
Traffic-related environmental problems	North-western part/city centre
Damage to green areas	North-western/north-eastern part
Soil pollution	North-western/north-eastern part
Air pollution	North-eastern part
Safety risks caused by industrial companies	Southern part
Water pollution	Southern part
Annoyance from malodour	Southern part

Source: Omnibus survey (Luijkx and Rijpma, 2001)

From the mentioned sources of annoyance *road traffic noise* appeared to be the most widespread source in this region. About 20% of the inhabitants mentioned to be annoyed by it, in spite of the relative high tolerance for noise of road traffic in comparison with other Dutch inhabitants. The noise problem was largest around busy roads. Nevertheless, noise from road traffic influenced the general opinion on the environment less inside compared to outside the region (Woudenberg and Elsman, 1998). *Industrial noise* appeared to be a more area-specific problem, but in the areas where it was present (near harbours and industry), it caused more annoyance and dissatisfaction. About 12% of the inhabitants were annoyed by this source. Especially in Heijplaat, a neighbourhood nearby the industry, industrial noise appeared to be a problem. Still noise from road traffic had more influence on the general opinion on the environment than industrial noise (Woudenberg and Elsman, 1998). *Aircraft noise* appeared to be a area-specific problem as well. In the neighbourhoods around Rotterdam Airport aircraft noise was the most important adverse aspect of the environment. *Air pollution* appeared to be the most important environmental stressor in the neighbourhoods around the harbour (Woudenberg and Elsman, 1998). A large proportion (20-30%) of the inhabitants living in the Rijnmond region were worried about a potential accident caused by the industry present in the surroundings. Surprisingly, all people feeling unsafe were not living within a safety contour of an industrial company. Generally inhabitants showed more interest in what to do if a disaster happens, than in the actual risk itself (Woudenberg and Elsman, 1998).

8.4 The socio-economic distribution of perceived environmental quality

A survey on the living situation in Rotterdam showed that the higher the average income of inhabitants in a neighbourhood, the more positive the appraisal of the general living conditions. However, this association was not so strong (Bik, 1999). In another research they

found a similar association in secondary analyses using the data of the survey ordered by the Province of South-Holland (Kamphuis, 1998). Lower educated people were more often annoyed than higher educated people, and the former evaluated the environment less positive than the latter (TNO in: Woudenberg and Elsman, 1998).
In the sustainability survey from the local statistical agency (COS) no differences were found between socio-economic categories in the mentioned most important problems in Rotterdam (Luijkx and Rijpma, 2001). Higher educated participants referred more often to environmental problems in general, while low educated participants referred more often to dog mess and noise annoyance caused by neighbours. In the table below it is indicated what socio-economic group mentioned an environmental problem most often.

Table 8.4 Overview of socio-economic categories mentioning a certain environmental problem most often

Environmental problem	*Most often mentioned by*
Annoyance from malodour	Low educated participants; scholars or students, people without a job
Littering and dog mess	Low/middle educated people; scholars and students
Soil pollution	Low and middle educated participants; people without a job
Noise annoyance	(Early) retired people; participants without a job
Safety risks caused by industrial companies	middle educated participants
Water pollution	Middle educated participants; scholars or students, (early) retired people
Damage to green areas	Middle/high educated participants; participants without a job
Traffic-related environmental problems	High educated participants; participants with a paid job
Air pollution	High educated people

Source: Omnibus survey (Luijkx and Rijpma, 2001)

Furthermore, it appeared that the higher the educational level, the more dissatisfied inhabitants were with the amount of public green areas (city parks and nature) in Rotterdam and surroundings. Higher educated participants, participants with a paid job and housewives and housemen preferred to have a forest in case a new nature area or recreational area would be developed, while low educated participants, scholars and students, and people without a job more often preferred a park.
Based on secondary analyses using ‘our’ database, we can only describe some preliminary results (Appendix 10). These results indicate that people with a higher income perceive air pollution, malodour and traffic more often as the largest problem than people with a lower income. Furthermore, citizens from a higher income category were more satisfied with the

amount and the quality of green areas in their neighbourhood than citizens from lower income categories. In addition, a lower percentage of the high-income citizens were often annoyed by noise compared to the lower income citizens.

8.5 The association between the ‘objective’ environmental indicators and perceived environmental quality

Woudenberg and Elsman concluded in their report on liveability in the Rijnmond region that generally environmental exposure is the most important determinant of annoyance, suggesting that there is a relation between ‘objective’ indicators for environmental quality and perceived environmental quality. Other factors, such as environmental consciousness and socio-psychological factors were also related to annoyance, but this association was much weaker than the association with exposure. Based on the available regional or local data, this association seemed to be clearly present for *noise from road traffic* in the Rijnmond; for *industrial noise* it was less clear, and for *aircraft noise* it was weak. The association between concentrations of *air pollution* and annoyance was strong. Air pollution and industrial malodour and the annoyance caused by these indicators was highly correlated. Most inhabitants mentioned industry as the most important source of malodour. However, for *risk exposure* the association with inhabitants feeling unsafe was weak. In areas without industry or transport routes people felt safe, while this was not the case if these objects were present. However, if such an object was present, distance to the object seemed to be not important (Woudenberg and Elsman, 1998).
Based on secondary analyses using ‘our’ database, it appeared that the associations between the ‘objective’ environmental indicators and the related perception on these issues were not very strong (Appendix 11). An exception was the association between the average amount of available public green areas and dissatisfaction with the amount and the quality of green areas in the neighbourhood, with the percentage of dissatisfied citizens increasing with a decreasing amount of available public green areas within a certain distance. Correlation was strongest at the distance of 1000 metres. Furthermore, an (unexpected) negative association between accumulated noise levels, aircraft noise and road traffic noise levels, was found with percentage of citizens often being annoyed by noise. The accumulated noise levels were positively associated with the percentage of citizens perceiving traffic to be the largest problem.

8.6 Summary of the results

- ‘Classical’ environmental problems (noise, air pollution, soil pollution, safety risks) appeared not to be the most important problems in the Rijnmond region and in society and not the most dissatisfying aspects in the Rijnmond region according to the inhabitants. In addition their influence on the general opinion on the quality of the local environment were small. At the same time presence or absence of noise was the most unpleasant or pleasant aspect for inhabitants of living in their neighbourhood.

- Inhabitants often defined environment broader, including littering and dog mess, and quality of public green areas as well. The inhabitants of Rotterdam perceived littering and dog mess to be the largest environmental problem. Of the more ‘classical’ environmental issues air pollution, often being associated with industry, was the most important problem. The opinion on the environmental situation in the Rijnmond region has improved since 1990, but in 1998 still 12% of the inhabitants was dissatisfied with the environmental situation in their neighbourhood the whole Rijnmond region.
- Traffic noise and in particular road traffic noise appeared to be the most important source of annoyance in the Rijnmond region as a whole. The survey data indicate that annoyance from road traffic noise is a widespread problem, while the other sources of annoyance such as noise and air pollution from industries, and aircraft noise are more area-specific problems. Littering and dog mess was most often mentioned in the city centre.
- In general, annoyance due to environmental problems was mentioned by all income categories, but the most often mentioned source of annoyance differed between the various income categories. Inhabitants from higher income categories perceived air pollution, malodour and traffic more often as the largest problem compared to citizens from the lower income categories, and referred more often to environmental problems in general. People from the lower income category were more often dissatisfied with the amount and quality of green areas in their neighbourhood than people from the former category. They referred more often to dog mess and noise annoyance caused by neighbours. Generally, inhabitants with a lower income were more often annoyed by environmental aspects than inhabitants with a higher income, but the association is weak.
- The association between ‘objective’ indicators and perception of the inhabitants is complex and needs further research. Results reported in literature and results from our analyses both run into the problem of lack of detailed spatial data. The reported results are thus preliminary. In literature only the association between road traffic noise and annoyance from this source, and between air pollution concentrations and annoyance are clear. For other environmental indicators (industrial noise, aircraft noise, safety risks) an association was present but weak, which was confirmed by our analyses. In addition, in our analyses associations between ‘objective’ environmental indicators were clearly present for the amount of available public green areas and satisfaction on the amount and quality of green areas in the neighbourhood in the expected direction. For noise an association was present as well, but in the opposite direction, with lower percentages of often annoyed inhabitants at higher noise levels.

9. The socio-economic distribution of environmental quality in the Rijnmond region: evidence for differences?

In this report we described an exploratory empirical case study on the socio-economic distribution of environmental quality in the Rijnmond region, the Netherlands. In this last chapter we discuss the evidence produced by this case study on this topic. In the first section we present the main conclusions of the case study, in the second section we pay attention to the most important methodological issues. We finish with some recommendations for further research.

9.1 Main conclusions of the Rijnmond case study

Main conclusions and implications of the case study on the socio-economic distribution of environmental quality in the Rijnmond region are summarised below.

a) ***Lower income areas are more often exposed to environmental 'bads' than higher income areas, but accumulation of environmental 'bads' is rare and is the same for all income categories, except for minimum-income areas.***
   In general, lower income areas were more often exposed to 'bads' then the higher income areas. An exception was found for aircraft noise, for which a consistent opposite result was found. Differences in environmental 'bads' between areas with different income levels were clear for exposure to NO_2 and presence of waste disposal sites and were less pronounced for noise and safety risks. In addition, areas with a higher percentage of non-western minorities appeared to be higher exposed to environmental 'bads' as well compared to areas with a lower percentage of non-western minorities.
   Although for separate environmental indicators the standards used in this study were exceeded, accumulation of environmental 'bads' occurred in only a low percentage of the zip code areas. In 3% of the 6-digit zip code areas, mainly located in the centre of the Rijnmond region, the standard for noise and NO_2 were both exceeded at the same time. There were no areas with an additional 'bad' present. Absolute differences between income categories were small. Based on the findings concerning accumulation of 'bads', a minimum or basic level of environmental quality, at which health and safety are protected, seems to be guaranteed for most inhabitants. Still minimum-income areas are exposed somewhat more often to accumulation of levels and noise and NO_2 above the standard at the same time.

b) ***There are differences between income categories in access to environmental amenities or 'goods'.***

In general, this case study shows that the higher the income, the higher the access to environmental 'goods'. These 'goods' include more quiet areas, especially when considering noise from railroad traffic and accumulated noise levels, a larger amount of public green area per inhabitant, less air pollution, and less waste disposal sites in the direct surroundings. An exception was aircraft noise, for which consistent opposite results were found. This might be explained by the fact that the airport is situated in the more rural part of the regio, where more high-income people live.

Considering the accumulation of environmental 'goods' shows that areas with a middle to high income level have about two to three times more often access to environmental 'goods' compared to the areas with mainly a minimum or low income level. Largest differences were observed when all environmental indicators selected for this study were included in the accumulation. Based on the indicators included in this study, a concentration of 'goods' was found in the northern and southern borders of the Rijnmond region, where the higher income population live.

Presence of these environmental 'goods' might be considered as having access to a nice and pleasant local environment. The fact that higher income categories have more often access to these environmental 'goods' might be assumed to be a result of market efficiency in the first place. People with a higher income can 'buy' more environmental amenities, by buying a dwelling in a neighbourhood with a better local environmental quality. On average, they have more freedom to choose the location where they want to live. In combination with the former conclusion, it might be discussed if there is a responsibility for policy to guarantee people more than a basic level of local environmental quality, also for people with a lower income.

c) ***All income categories report annoyance due to presence of a polluting source, but the source of annoyance differs between income categories and is often area-specific.***

In perceived environmental quality there are socio-economic differences as well. The source on which inhabitants report to be annoyed mostly differs between income categories. It seems to be related to local sources, and is therefore area-specific. Lower income people are especially annoyed by dog mess and noise annoyance from neighbours. Higher income people are more annoyed by air pollution, malodour and traffic. Thus although people with higher income seem to have more access to environmental amenities, a part of them also face annoyance due to environmental pollution. Annoyance due to environmental pollution thus occurs at all income levels. Taking into account the issue of congestion in the densely populated and highly industrialised Rijnmond region, this is not surprising. In a densely populated country as the Netherlands, and especially in the western part, it is almost impossible to escape from annoying environmental sources, even for people with a high income. This has also consequences for the debate on efficiency and equity. For policy makers it might be more difficult to guarantee a nice and pleasant local environment for everyone in areas facing this congestion issue than in areas that do not have this problem.

d) 'Objective' environmental quality is related to annoyance due to some of the environmental pollutants.

The association between 'objective' environmental quality (e.g. air quality levels) and 'subjective' or perceived environmental quality (e.g. annoyance by malodour) is complex and certainly needs further research. Because of a lack of detailed data on the perception of inhabitants, the insight we get from this study in the association between 'objective' indicators and perceived environmental quality is limited. However, the results found in literature on local and regional studies and our own analyses give some indications that 'objective' indicators are related to annoyance of inhabitants concerning these environmental indicators. This corresponds with findings from various international studies (e.g. Miedema and Oudshoorn, 2001). In this research on environmental equity this is important. These results indicate that e.g. policy effects to reduce noise levels would be effective in reducing annoyance. At the same time it is known that personal and contextual variables influence people's perception on their local environment, which might limit the effect of policy measure to a certain extent.
To what extent these policy measures would also improve the general perception on the local environment of inhabitants is questionable. Several Dutch studies show that satisfaction with the local environment is mainly determined by the extent of satisfaction with the dwelling, followed at distance by the situation in the streets, satisfaction with neighbours, and with facilities in the neighbourhood in Rotterdam. The environmental situation and satisfaction with parks show a much weaker, but significant association with the general satisfaction with the local environmental (e.g. Bik, 1999).

9.2 Methodological issues

While planning and performing the analyses for this report, decisions needed to be made which might have influenced our conclusions on the socio-economic distribution of local environmental quality in the Rijnmond region. Among these issues is the *perspective* used for the study, the *selection and definition of indicators, data availability*, and *methods of analysis* used for this case study.

Perspective used in this study

In this study we often used environmental policy as the *perspective,* for example in using a broader definition of environmental quality and in focusing on differences at the local level. In defining 'goods' and 'bads' and in defining the levels of accumulation we more or less used the perspective used in policy, by using standards for noise and air pollution and concepts from policy documents, such as a 'healthy and safe' environment and a 'nice and pleasant' environment (e.g. the Dutch National Environmental Plan 4 (2001)). Another perspective could be e.g. the perspective of inhabitants, and basing the levels of accumulation for example on what they perceive as the most important environmental issues. In addition, we focussed on the place where people live and not e.g. on their workplace or schools. We are aware that a part of the population spends a great part of their time there, but we chose to demarcate our study to the place where people live. A different perspective might lead to a different story on the same topic.

Selection and definition of indicators
Concerning the selection of indicators, we think that including more than one environmental indicator has proved to be useful to get a more complete insight in local environmental quality in a neighbourhood and in the accumulation of environmental quality for a certain neighbourhood and for a certain population group. It might give hands for policy makers to determine where measures are needed first. In addition, adding the perception of inhabitants as well ('subjective' indicators) gives a more complete insight than focussing only on 'objective' indicators. The association between the 'objective' and 'subjective' indicators is not so clear yet. More research is necessary to get insight if inhabitants judge their local environment the same, as is done based on the 'objective' indicators, often used in policy documents. If this is not the case, e.g. if certain standards for protection of health or safety are exceeded and inhabitants perceive environmental quality in their neighbourhood as 'good', they are either not aware of the bad situation, or they do not care. Another possible explanation is that they care more about other factors of the local environment. If they are not aware, this could be due to lack of information, and policy makers could provide the inhabitants with information. This issue is an important topic in environmental justice research in the USA as well, in which not having all the information to make an balanced decision e.g. while looking for a dwelling is sometimes interpreted as being not fair. Recently in the Netherlands policymakers an others show initiatives to improve the access to information on local environmental quality (e.g. 'Recht om te weten.nl' ('Right to know'), and activities being part of the Action Programme on Environment and Health).
The spatial scale of interest, namely the household level, and the definition of the study area determined the selection of environmental indicators and its definition as well. For example, global warming issues are out of the scope, while typical local environmental issues, such as noise, traffic-related air pollution (such as NO_2), safety risks and soil pollution, were within the scope of this study and were therefore selected.
In this study income was selected as the socio-economic indicator, partly because it was required by the OECD. However, following e.g. the discussion in many American studies on environmental equity, ethnicity might be an important socio-economic indicator as well. Based on our exploratory analyses this was confirmed for the Dutch situation as well. In addition, the educational level, age or stage of life, or job status might also be good socio-economic indicators. At the same time, it might be assumed that these indicators are highly correlated with income. So in that sense too, income might be assumed to be a good socio-economic indicator. However, according to our preliminary results presence of non-western minorities is an influential socio-economic indicator as well.

Another interesting topic for further research is the inclusion of indicators that might act as modifiers or confounders, such as urbanisation degree for example (lower income people live more often in more urbanised areas, where environmental quality is often worse). In the absence of a widely accepted theoretical framework it remains the question what indicators should be selected as potential confounders? And what is their effect on the socio-economic distribution of environmental quality? Are they specific for a certain region? If they appear to have a great effect on the distribution, and they are not taken into account while assessing the socio-economic differences, this might directly lead to inaccurate conclusions with all its consequences. Therefore it is important to study the role of this type of indicators and will get further attention in the continuation of this research.

We defined the indicators based on clear, but also debatable criteria, related to the aim of the study and the distinction in ‘goods’ and ‘bads’. In addition, data availability determined if the desirable definition could be used or not. Defining the indicators was not always easy, especially if standards or reference values did not exist. We tried to use official standards, and, if not available, we relied on expert judgement (e.g. for the minimum amount of available public green areas required per inhabitant). The implication for the selected indicators is explained below.
For *noise* Dutch standards were available, making it easier to define the indicator in an objective way: the percentage of (6-digit or 4-digit zip code) areas with a noise level of 65 decibel (dB(A)), a Dutch standard, was considered to be an environmental ‘bad’, while the percentage of areas with a noise level below 50 dB(A), the Dutch target value, was considered to be an environmental ‘good’. Noise from railroad traffic, road traffic and aircraft and accumulated noise of these sources are included in this report because of data availability on a detailed spatial scale level. However, based on the study area’s characteristics, industrial noise and noise from neighbours are important as well, but no digital, spatially detailed data were available for these indicators.
For *air pollution*, data were available for NO_2 and NO_x, both at the front of a dwelling and at the pavement. From a human health point of view NO_2 is more important than NO_x; therefore we present only results for NO_2 in this report. Although in our opinion the NO_2 concentration at the front represents human exposure better than at the pavement, the standard for NO_2 is based on NO_2 concentration on the pavement. Therefore we selected both NO_2 at the front of dwellings and NO_2 concentration on the pavement. The latter was used to define accumulation of environmental ‘goods’ and ‘bads’. For NO_2 the European standard of 40 microgram per cubic metre (40 $\mu g/m^3$) was used; areas with concentrations above this level were defined as ‘bad’ while areas with a concentration below this standard were defined as ‘good’.
For *public green areas*, we used the amount of it per inhabitant within a certain distance. Both data on availability (taking into account the amount of people with whom one has to share it) and accessibility (not taking this into account) were available. No legal standards currently exist. Because Dutch experts stated that less than 50 m^2 per inhabitant of available green within a distance of 500 metres (5 minutes walking distance) can be considered to be

‘bad’, and more of it within that distance is ‘good’, we used this to define ‘good’and ‘bad’. For the other analyses, we showed the amount available public green areas within several distances (200, 500 and 1000 metres), because we did not know what distance would be most relevant.

Based on expert judgement the *presence of dwellings within a safety risk contour* was in any case considered to be ‘bad’, and only areas with no dwellings within a safety risk contour were defined to be ‘good’ in the analyses presented in chapter 7. Again, for the other analyses we used the percentage of dwellings within a safety risk contour without further definition.

Finally, the *presence of waste disposal site* was included because it is often used in American studies. Data on waste disposal sites included waste processing, exploitation of refuse dump, and disposal of contaminated soil. It is important to realise that waste disposal sites in the Netherlands are different and probably cleaner than waste disposal sites in the USA. The use of this indicator is therefore debatable. Like for dwellings within a safety risk contour, we defined presence of any waste disposal site within 250 metres to be ‘bad’, and no waste disposal site within 1000 metres to be ‘good’. For the other analyses we used the percentage of areas with a waste disposal site within a certain distance (250, 500, and 1000 metres), because we did not know what distance would be most relevant. As becomes clear from the results presented in this report on the different distances, results on the socio-economic disparities for various distances differ. This points out again the effect of the selected definition on the outcome.

For the socio-economic indicator *income* the definition was based on data availability, and was therefore different at the 6-digit and the 4-digit zip code level. For the 4-digit zip code level, four different definitions were possible. The results of the univariate regression analyses with these indicators show that the definition influences the conclusion if there are differences in environmental quality for different income categories. In most of the cases the indicator with income categories shows a significant relation, while the average income indicators do not. This indicates that the relation between environmental indicator and income is non-linear. This suggests that an indicator with income categories is a better indicator when analysing the socio-economic distribution. Furthermore, in our opinion, it is often more appealing to policy makers to hear the difference between a high-income and a low-income category, than to hear that the environmental quality is decreases with this and that amount per euro (dollar) income.

Data availability and spatial scale

So far we used recent quantitative data from mainly *national* databases to have comparable data for the whole region and to be able to extent these analyses to a larger part of the country as a part of our larger broader investigation on environmental inequity in the Netherlands. For some important indicators digital data were lacking, e.g. for soil quality, for industrial noise and for noise from shipping. Lack of these data therefore limited the scope of the research. Probably these data are available from regional or local research, but they are often more difficult to get.

Because the 6-digit zip code level was assumed to approach the neighbourhood best, we performed analyses on this level in the first place. For both local environmental quality such as noise and air pollution and for a homogeneous income category, this level was judged to be more accurate than the 4-digit zip code level. However, fewer data on other socio-economic indicators (such as ethnicity and education level) were available at that level compared to the 4-digit zip code level. In addition, the income indicator was derived from telephonic interview data on the income of the contacted household and is not based on counted data.
Some of the available data showed shortcomings, which might have influenced the results. For example, the NO_2 data coming from a traffic model, which only calculated levels on the street and its direct surroundings. Therefore many 6-digit areas had a zero concentration, while in reality this concentration might have been higher. However, excluding the zero concentration areas leads to the same conclusions as presented here.
We performed some analyses on the 4-digit zip code level. For these analyses data on the environmental indicators were aggregated to the 4-digit zip code level, by averaging the values of all 6-digit areas within the 4-digit zip code area. However, this wipes out the extremes, and it blurs the actual differences in e.g. levels of noise and NO_2. According to a Dutch acoustical expert, we could use the aggregated percentage of dwellings with a noise level of 65 dB(A) and less than 50 dB(A) instead of focussing on the average noise level in the 4-digit zip code area.
Another data issue concerned the data on perception. These are available from surveys, in which a sample of the total population in the Rijnmond region or in Rotterdam has been approached. The sample size was too limited to analyse on the 6-digit zip code level, and it is debatable if the analyses on the 4-digit zip code level produce accurate results (with sometimes less than 100 observations per 4-digit zip code area). Nevertheless, the first analyses show consistent results. However, the results should be interpreted carefully. By using individual data, if available, and assuming that the environmental data available on the 6-digit zip code level to be representative for all respondents in that area, probably more accurate results might be obtained. This will be part of future analyses. In addition, we could get more insight in the perception of the inhabitants from literature (Kamphuis, 1998; Woudenberg and Elsman, 1998; Bik, 1999; Luijkx and Rijpma, 2001).

In general, we learned from our analyses that the 6-digit zip code level is the preferred spatial scale level to perform the analyses on; the 4-digit zip code level is the second best choice, if neighbourhood data and 6-digit zip code data are not available. In future analyses we will perform also analyses in which data on 4-digit and borough level are disaggregated to the 6-digit zip code level. Probably multilevel analyses will be performed as well.

For the analyses in this report we used recent data to describe the current situation, but ‘historical data’ are needed to be able to describe developments, necessary to analyse causes of environmental equity. This would be a useful addition to the information presented here.

Finally we need to remark that data are derived in different years from different databases of different quality. This could have influenced the results of this study in an unknown way, and made the analyses more complex by the way data were available (as numbers, averages, or percentages).

Methods of analysis
The statistical methods used so far might be extended by testing on statistical significance, by including spatial correlations and by performing multilevel analyses. The use of categorical data and evaluation of the weighing method are part of the future research on environmental inequity in the Netherlands.

9.3 Issues needing further research and discussion

In the former sections we already mentioned several methodological issues on which further research and discussions in our opinion are necessary. In this section we give more remarks on the contents of future research.
Insight in the perception of inhabitants of the areas being studied is important, as pointed out earlier. A related topic is the association between objective and subjective indicators: if environmental quality is 'good' measured as with objective indicators, is it also perceived 'good' by the inhabitants? If not, what causes these differences? And is there a relation with the distribution of environmental 'goods' and 'bads'? Therefore we suggest including indicators on perception as well while assessing the socio-economic distribution on environmental quality.
This leads us to the question what the causes are of the current 'unequal' distribution. In this case study we have not touched this subject yet. In literature, several potential causes have been mentioned: market efficiency, historical planning processes, and the fact that minorities and poorer people have fewer opportunities to defend themselves in planning processes (a.o. Mohai and Bryant, 1992; Hamilton, 1995; Goldman, 1996, Coenen and Halfacre, 2000). For policy makers it might be particularly of interest to know the effect of policy on this distribution. This does not only require insight in historical developments, and thus requires historical data, but it also requires insight in the background of policy decisions in the past. A good method to get this insight is interviewing national, regional and local key persons (policy makers and planners) on this topic. These interviews can at the same time be used to evaluate the outcomes of the reported case study. This will be a part of the continuation of this research.
In order to get more insight in environmental inequity in the Netherlands, it is important to choose other cases as well, to test of the explanations for the occurrence of environmental inequity found in the Rijnmond region are valid in other regions as well.
Based on additional empirical studies and theoretical discussions in the continuation of this research on environmental equity in the Netherlands, we want to get more insight in especially the role of policy in this issue. Main question for us is; what is the position of

Dutch policy concerning environmental equity and what are the consequences of that? With this research we want to make people, especially policymakers aware of the environmental equity issue in the Netherlands and their role in it.

References

Bik, M. (1999). Environmental annoyance and perception of the local environment in Rotterdam (in Dutch). Centre for Research and Statistics (COS).

Bowen, W. (2002). An analytical review of environmental justice research: what do we really know? Environmental Management, 29 (1), 3-15.

COS (s.a.). Neighbourhood Information Digital. SWING Online (in Dutch). On May 18th found on the World Wide Web <http://rotterdam.buurtmonitor.nl/sol.net/(tyng0kepmrkkg345ter1il45)/swingonlineframes.aspx?application=rotterdam>

Coenen, F. and Halfacre, A. (2000).The distribution of environmental effects and environmental risks in the Dutch population as a policy problem: ‘Environmental injustice’ in the Netherlands (in Dutch). Beleidswetenschap: kwartaalschrift voor beleidsonderzoek en beleidspraktijk. Vol. 14 (4): 316-339.

DCMR (2002). The environment in the Rotterdam region (in Dutch). Schiedam.

Goldman, B.A. (1996). What is the future of environmental justice? Antipode. Vol. 28 (2): 122-141.

Hamilton, J.T. (1995). Testing for environmental racism: prejudice, profits, political power? Journal of Policy Analysis and Management. Vol. 14 (1): p. 107-132

Kamp, I. van, Leidelmeijer, K., Marsman, G., Hollander, A.E.M. de (2003). Urban environmental quality and human well-being: Towards a conceptual framework and demarcation of concepts; a literature study. Landscape and Urban Planning. Vol. 65 (1-2): p.5-18

Kamphuis, J. (1998). Survey on the perception of the environment in South-Holland 1998 (in Dutch). Province of South-Holland, The Hague.

Luijkx, K.G. and Rijpma, S.G. (2001). Inhabitants of Rotterdam about the sustainable city-Results of the Omnibus interview 2001(in Dutch). COS, Rotterdam.

Miedema, H.M.E. and Oudshoorn, C.G.M. (2001). Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and their Confidence Intervals. Environmental Health Perspectives. Vol. 109 (4): p. 409-416

Mohai, P. and Bryant, B. (1992). Race, poverty and the environment-The disadvantaged face greater risks. EPA Journal. Vol. 18 (1) : 6-9

RIVM (2000). National Environmental Outlook 5 (2000-2030) (in Dutch). Samson bv, Alphen aan de Rijn, The Netherlands.

RIVM (2001). National Environmental Balance. Samson bv, Alphen aan de Rijn, the Netherlands.

Roberts, S. (2000). Environmental justice: examining the role of risk assessment. Human and Ecological Risk Assessment. Vol. 6 (6): p. 537-540.

University of Michigan (1997). Background: The Problem of Disproportionate Burdens. On February 17th 2004 found on World Wide Web <http://www.umich.edu/~snre492/>

Walda, I. (2002). Is there a relation between socio-economic status and exposure to environmental noise? (in Dutch) Geluid Issue 2,: 57-60.

Weintraub, I. Fighting Environmental Racism: a selected annotated bibliography. Electronic Green Journal, Issue 1, June, 1994 On February 17th 2004 found on the World Wide Web <http://www.mapcruzin.com/EI/ejigc.html>

Woudenberg, F. and Elsman, L. (1998). Liveability in Rijnmond (in Dutch). Report of the Municipal Health Services (GGD), Rotterdam.

APPENDIX 1A Definition of indicators and data available at the 6-digit zip code level

Type of indicator	Indicator	Definition used in the analyses	Data source and year of data collection
Environmental indicator ('objective')	Air quality	NO_2 concentration at the front of the dwelling (in microgram/cubic metre ($\mu g/m^3$)) NO_2 concentration on pavement (in $\mu g/m^3$) NO_2 concentration at the front of the dwelling larger than 40 $\mu g/m^3$ (Dutch standard for NO_2) NO_2 concentration on pavement larger than 40 $\mu g/m^3$	Recalculated concentrations for 2000 using data from the 'RVMK' ('Regionale verkeersmilieukaart').
	Noise	Noise level of different sources (railroad traffic, road traffic and aircraft) separately and accumulated in decibels (dB(A)) Noise level of these sources (separately and accumulated) above 65 dB(A) (Dutch standard for noise) Noise level of these sources (separately and accumulated) below 50 dB(A) (Dutch target value for noise)	EMPARA- Noise model RIVM Various databases used as input for the model
	Public green areas (e.g. parks, forest)	Availability of public green areas (parks, forest, recreational and nature) Availability refers to access of public green areas plus taking into account the number of people sharing it (between 200 and 1000 metres)	'Geomarktprofiel' (BRIDGIS) 2000 and Soil Statistics ('Bodemstatistiek') (CBS) 1996
	Safety risks	Number and percentage of dwellings inside and outside the risk contour of specific companies	RIVM information on risk contours of certain firework industries; ACN data on locations of dwellings, 2000
	Waste disposal sites in direct surroundings	Presence (0/1) of waste disposal site (waste processing, exploitation of refuse dump, disposal of contaminated soil) within a certain distance (250, 500 and 1000 metres)	LISA, 2001 (sbi93 code O9000003)
Socio-economic indicator	Income	The most common income level (estimated based on telephonic interviews) within the 6-digit zip code area (income unknown, high, above average, average, low, minimum, various)	'Geomarktprofiel' (BRIDGIS) 2000

APPENDIX 1B Definition of indicators and data available at the 4-digit zip code level

Type of indicator	Indicator	Definition used in the analyses	Data source and year of data collection
Environmental Indicator	See Appendix 1A.	Average of data available at the 6-digit zip code level	See Appendix 1A.
Socio-economic indicators	Income	Average income per inhabitant	CBS 1998
		Average income per income recipient	CBS 1998
		Percentage of people within a certain income category (income up to 30,000, between 30-50,000, between 50-80,000 and more than 80,000 guilders/year (1 guilder is about 0.45 euro))	ABF 1998
		Percentage of people with a certain income level: high income (above 80-percentile of national income distribution=45,900 guilders/year), low (below 40-percentile of national income distribution=26,500 guilders a year)	CBS 1998
	Ethnicity	Percentage of non-western minorities	CBS 1999
Other indicators used	Housing price	Average housing price (‘WOZ’ value)	CBS 1999

APPENDIX 2 Correlation matrix of income indicators, % of non-western minorities and average housing price

(4-digit zip code areas; Spearman correlation coefficients and p-value, not weighted)

	1	*2*	*3a*	*3b*	*3c*	*3d*	*4a*	*4b*	*5*	*6*
1		0.85 <0.0001	-0.54 <0.0001	-0.15 0.1374	0.53 <0.0001	0.67 <0.0001	-0.78 <.0001	0.82 <0.0001	-0.75 <0.0001	0.72 <0.0001
2			-0.78 <0.0001	-0.17 0.0865	0.79 <0.0001	0.89 <0.0001	-0.95 <0.0001	0.98 <0.0001	-0.75 <0.0001	0.89 <0.0001
3a				-0.15 0.12	-0.96 <0.0001	-0.79 <0.0001	0.79 <0.0001	-0.81 <0.0001	0.71 <0.0001	-0.80 <0.0001
3b					0.00 0.9587	-0.32 0.0006	0.08 0.4062	-0.20 0.0435	0.06 0.5770	-0.23 0.0176
3c						0.78 <0.0001	-0.79 <0.0001	0.82 <0.0001	-0.74 <0.0001	0.80 <0.0001
3d							-0.84 <0.0001	0.89 <0.0001	-0.71 <0.0001	0.90 <0.0001
4a								-0.91 <0.0001	0.67 <0.0001	-0.81 <0.0001
4b									-0.80 <0.0001	0.90 <0.0001
5										-0.78 <0.0001

1: Average income per inhabitant
2: Average income per income recipient
3a: % of people with income below 30,000 guilders per year
3b: % of people with income between 30,000-50,000 guilders per year
3c: % of people with income between 50,000-80,000 guilders per year
3d: % of people with income above 80,000 guilders per year
4a: % low income; 4b: % high income
5: % non-western minorities
6: average housing price

APPENDIX 3 General description of data available on the 6-digit level

-not weighted-

Type of indicator	Indicator	Number of 6-digit zip code areas	Average (mean)	Standard deviation	Range
Environmental indicator	Accumulated noise level (railroad traffic, aircraft, road traffic(decibel (dB(A)))	19,495	57.5	6.2	33-81
	Noise level railroad traffic (dB(A))	19,495	45.3	9.8	28-81
	Noise level aircraft (dB(A))	19,495	22.4	10.4	14-73
	Noise level road traffic (dB(A))	19,495	56.2	6.3	31-81
	NO_2 level front (micrograms per cubic metre (μg/m^3)), all areas included	19,495	17.4	19.1	0-57
	NO_2 level pavement (μg/m^3), all areas included	19,495	20.0	20.7	0-65
	Available public green areas (square metres per inhabitant (m^2 /inh)) within 200 metres distance	19,481	53.5	679.5	0-32,346
	Available public green areas (m^2 /inh) within 500 metres distance	19,494	68.5	1064.6	0-61,627
	Available public green areas (m^2 /inh) within 1000 metres distance	19,495	56.2	852.1	0-66,258
	Percentage of dwellings within a safety risk contour	19,616	5.1	21.8	0-100
	Proportion of 6-digit zip code areas with a waste disposal site within 250 metres	19,495	0.005	0.068	0-1
	Percentage of 6-digit zip code areas with a waste disposal site within 500 metres	19,495	0.015	0.123	0-1
	Proportion of 6-digit zip code areas with a waste disposal site within 1000 metres	19,495	0.070	0.255	0-1

APPENDIX 4 General description available data on 4-digit zip code

-not weighted-

Type of indicator	Indicator	Number	Average (mean)	Standard deviation	Range
Environmental indicator	Average accumulated noise level (railroad traffic, aircraft, road traffic (dB(A))	116	57.6 [1]	4.6	43.5-68.0
	Average noise level railroad traffic (dB(A))	116	45.2 [1]	9.8	28.0-67.7
	Average noise level aircraft (dB(A))	116	23.3 [1]	10.8	14.0-58.1
	Average noise level road traffic (dB(A))	116	56.0 [1]	4.2	42.9-65.0
	Average NO_2 level front (micrograms per cubic metre (μg/m^3))	116	15.2 [1]	8.7	0-34.4
	Average NO_2 level pavement (μg/m^3)	116	17.7 [1]	9.1	0-39.2
	Average available public green areas (square metres per inhabitant (m^2 /inh)) within 200 metres distance	116	213.0	936.8	0-8940
	Average available public green areas (m^2 /inh) within 500 metres distance	116	508.9	2993.1	0-27591
	Average available public green areas (m^2 /inh) within 1000 metres distance	116	708.9	4835.5	0.1-49521
	Average percentage of dwellings within a safety risk contour	117	10.8	28.4	0-100
	Average proportion of 6-digit zip code areas with a waste disposal site within 250 metres	116	0.010	0.048	0-0.367
	Average proportion of 6-digit zip code areas with a waste disposal site within 500 metres	116	0.026	0.099	0-0.600
	Average proportion of 6-digit zip code areas with a waste disposal site within 1000 metres	116	0.085	0.220	0-1
Socio-economic indicator	Percentage of people with income below 30,000 guilders/year	114	40.4	11.5	12.5-61.2
	Percentage of people with income above 80,000 guilders/year	114	7.9	4.8	1.4-23.7
	Percentage of people with a low income	104	42.7	8.6	17-63
	Percentage of people with a high income	103	18.4	8.6	6-43
	Average income level per inhabitant	104	22229	3679.5	14,400-34,000
	Average income level per person with income	104	32694	4789.3	26,000-48,600
	Percentage of non-western minorities	103	22.0	18.7	2-73
	Average housing price (‘WOZ’ value)	103	142.9	56.14	68-333

[1] linear average

APPENDIX 5 The socio-economic distribution of noise in the Rijnmond region

-weighted-

Income category	Accumulated noise levels *AM[1] (sd)*	Accumulated noise levels > 65 dB(A) *% of areas*	Accumulated noise levels < 50 dB(A) *% of areas*
High	**55.7 (0.04)**	**6.0**	**11.3**
Above average	**56.2 (0.05)**	**7.6**	**13.3**
Average	**56.8 (0.05)**	**7.2**	**12.0**
Low	**57.4 (0.04)**	**7.9**	**8.6**
Minimum	**57.8 (0.04)**	**9.3**	**7.5**
Various	57.5 (0.05)	8.0	10.4
Unknown	60.5 (0.01)	38.5	5.5

Income category	Noise levels from aircraft *AM[1] (sd)*	Noise levels from aircraft > 65 dB(A) *% of areas*	Noise levels from aircraft < 50 dB(A) *% of areas*
High	**25.4 (0.07)**	**0**	**96.5**
Above average	**25.4 (0.08)**	**0**	**97.1**
Average	**23.0 (0.08)**	**0**	**97.5**
Low	**20.9 (0.07)**	**0**	**98.4**
Minimum	**19.2 (0.06)**	**0**	**98.7**
Various	23.4 (0.08)	0	97.7
Unknown	17.3 (0.01)	0	100

Income category	Noise levels from railroad traffic *AM (sd)*	Noise levels from railroad traffic > 65 dB(A), *% of areas*	Noise levels from railroad traffic < 50 dB(A), *% of areas*
High	**40.7 (0.07)**	**0.6**	**76.4**
Above average	**42.1 (0.08)**	**1.7**	**73.3**
Average	**44.2 (0.08)**	**2.0**	**70.5**
Low	**46.0 (0.07)**	**2.9**	**65.5**
Minimum	**46.9 (0.06)**	**2.6**	**62.5**
Various	45.0 (0.08)	2.7	67.4
Unknown	49.2 (0.02)	22.8	56.5

Income category	Noise levels from road traffic *AM[1] (sd)*	Noise levels from road traffic > 65 dB(A) *% of areas*	Noise levels from road traffic < 50 dB(A) *% of areas*
High	**54.6 (0.05)**	**4.2**	**17.8**
Above average	**55.0 (0.05)**	**5.3**	**17.5**
Average	**55.6 (0.05)**	**4.6**	**15.9**
Low	**56.0 (0.04)**	**4.9**	**12.9**
Minimum	**56.3 (0.04)**	**5.5**	**12.1**
Various	56.1 (0.05)	4.6	13.7
Unknown	57.6 (0.01)	12.9	5.5

[1]AM:arithmetic mean; sd: standard deviation

APPENDIX 6 The socio-economic distribution of air pollution in the Rijnmond region

-weighted-

Income category	NO_2 levels at the front (all 6-digit zip code areas included) *AM (sd)*[1]	NO_2 level at the front > 40 ųg/m^3 (all 6-digit zip code areas included) *% of areas*	NO_2 levels at the front without zero concentration areas *AM (sd)*[1]	NO_2 level > 40 ųg/m^3 at the front without zero concentration areas *% of areas*
High	**12.9 (117.2)**	**5.9**	**35.6 (33.7)**	**16.3**
Above average	**13.4 (126.4)**	**7.1**	**35.7 (40.0)**	**18.8**
Average	**16.3 (130.7)**	**10.5**	**36.9 (38.6)**	**23.7**
Low	**18.3 (136.7)**	**15.9**	**38.4 (38.7)**	**33.3**
Minimum	**21.6 (136.7)**	**20.6**	**38.9 (36.3)**	**37.1**
Various	16.1 (133.8)	9.2	36.2 (40.8)	20.7
Unknown	21.2 (22.9)	5.3	38.2 (3.6)	9.6

Income category	NO_2 levels on the pavement (all 6-digit zip code areas included) *AM (sd)*[1]	NO_2 level on the pavement >40 ug/m3 (all 6-digit zip code areas included) *% of areas*	NO_2 levels on the pavement without zero concentration areas *AM (sd)*[1]	NO_2 level > 40 ųg/m^{3}on the pavement without zero concentration areas *% of areas*
High	**15.7 (133.1)**	**17.6**	**39.6 (40.9)**	**44.3**
Above average	**16.1 (140.3)**	**15.9**	**38.8 (45.6)**	**38.4**
Average	**18.7 (141.6)**	**21.2**	**39.6 (42.7)**	**45.0**
Low	**20.5 (147.1)**	**27.9**	**41.2 (42.1)**	**55.9**
Minimum	**23.9 (146.4)**	**36.5**	**41.9 (38.4)**	**64.0**
Various	18.8 (147.2)	21.6	39.5 (47.0)	45.4
Unknown	23.3 (23.0)	5.8	38.7 (5.3)	9.7

[1]AM:arithmetic mean; sd: standard deviation

APPENDIX 7 The socio-economic distribution of available public green areas in the Rijnmond region - weighted

Income category	% of areas with < 50 m^2 of public green areas available per inhabitant within 500 m
High	**77.8**
Above average	**85.8**
Average	**89.4**
Low	**92.1**
Minimum	**92.6**
Various	87.1
Unknown	85.6

APPENDIX 8 The socio-economic distribution of environmental indicators: results of univariate regression analyses

- 4-digit zip code level, not weighted -

Environmental indicator (outcome)	Socio-economic indicator: **income**, defined as:	R^2	p-value
Accumulated noise	Average income per inhabitant	0.0002	0.8977
	Average income per income recipient	0.0204	0.1478
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.1474**	**0.0005**
	Percentage of people with a certain income level (high, mid, low)	0.0277	0.2458
Noise from railroad traffic	Average income per inhabitant	0.0163	0.1965
	Average income per income recipient	0.0605	0.0119
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.1736**	**0.0001**
	Percentage of people with a certain income level (high, mid, low)	0.0604	0.0444
Aircraft noise	Average income per inhabitant	0.0588	0.0131
	Average income per income recipient	0.0670	0.0080
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.1967**	**<0.0001**
	Percentage of people with a certain income level (high, mid, low)	0.1486	0.0003
Noise from road traffic	Average income per inhabitant	0.0002	0.8979
	Average income per income recipient	0.0186	0.1671
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.1795**	**<0.0001**
	Percentage of people with a certain income level (high, mid, low)	0.0340	0.1772
NO_2 front	Average income per inhabitant	0.0319	0.0695
	Average income per income recipient	0.0671	0.0079
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.3376**	**<0.0001**
	Percentage of people with a certain income level (high, mid, low)	0.1126	0.0025
NO_2 pavement	Average income per inhabitant	0.0156	0.2071
	Average income per income recipient	0.0547	0.0169
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.3336**	**<0.0001**
	Percentage of people with a certain income level (high, mid, low)	0.0942	0.0071

Environmental indicator (outcome)	**Socio-economic indicator:** **income**, defined as:	**R^2**	**p-value**
Available public green areas within 200 m	Average income per inhabitant	0.0835	0.0029
	Average income per income recipient	0.0977	0.0012
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.1730**	**0.0001**
	Percentage of people with a certain income level (high, mid, low)	0.0463	0.0937
Available public green areas within 500 m	Average income per inhabitant	0.0913	0.0018
	Average income per income recipient	**0.1503**	**<0.0001**
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	0.0415	0.1966
	Percentage of people with a certain income level (high, mid, low)	0.0827	0.0134
Available public green areas within 1000 m	Average income per inhabitant	0.0952	0.0014
	Average income per income recipient	**0.0986**	**0.0012**
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	0.0449	0.1664
	Percentage of people with a certain income level (high, mid, low)	0.0948	0.0069
Dwellings with a safety risk contour	Average income per inhabitant	0.0001	0.9313
	Average income per income recipient	0.0081	0.3645
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.0563**	**0.0937**
	Percentage of people with a certain income level (high, mid, low)	0.0037	0.8304
Presence of a waste disposal site within 250 m	Average income per inhabitant	0.0075	0.3833
	Average income per income recipient	0.0016	0.6901
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.0309**	**0.3251**
	Percentage of people with a certain income level (high, mid, low)	0.0037	0.8307
Presence of a waste disposal site within 500 m	Average income per inhabitant	0.0174	0.1820
	Average income per income recipient	0.0064	0.4185
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.0254**	**0.4168**
	Percentage of people with a certain income level (high, mid, low)	0.0083	0.6576
Presence of a waste disposal site within 1000 m	Average income per inhabitant	0.0212	0.1403
	Average income per income recipient	0.0122	0.2639
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.0253**	**0.4191**
	Percentage of people with a certain income level (high, mid, low)	0.0064	0.7264

APPENDIX 9 Results of univariate regression analyses on the association between the presence of non-western minorities and environmental quality, and between income and environmental quality adjusted for the presence of non-western minorities

- 4-digit zip code level, not weighted -

Environmental indicator (outcome)	**Socio-economic indicator:** **income**, defined as:	R^2	**p-value**
Accumulated noise	Average income per inhabitant	0.0539	0.0646
	Average income per income recipient	0.0177	0.4140
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.1693**	**0.0010**
	Percentage of people with a certain income level (high, mid, low)	0.0501	0.1711
	Percentage of non-western minorities	0.0143	0.2288
Noise from railroad traffic	Average income per inhabitant	0.1479	0.0004
	Average income per income recipient	0.1030	0.0046
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.1852**	**0.0004**
	Percentage of people with a certain income level (high, mid, low)	0.1139	0.0081
	Percentage of non-western minorities	0.0950	0.0015
Aircraft noise	Average income per inhabitant	**0.2819**	**<0.0001**
	Average income per income recipient	0.2577	<0.0001
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	0.2590	<0.0001
	Percentage of people with a certain income level (high, mid, low)	0.2671	<0.0001
	Percentage of non-western minorities	0.2437	<0.0001
Noise from road traffic	Average income per inhabitant	0.0303	0.2178
	Average income per income recipient	0.0096	0.6219
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.2210**	**<0.0001**
	Percentage of people with a certain income level (high, mid, low)	0.0479	0.1885
	Percentage of non-western minorities	0.0037	0.5436

Environmental indicator (outcome)	**Socio-economic indicator: income**, defined as:	**R^2**	**p-value**
NO_2 front	Average income per inhabitant	**0.4134**	**<0.0001**
	Average income per income recipient	0.3141	<0.0001
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	0.3848	<0.0001
	Percentage of people with a certain income level (high, mid, low)	0.3188	<0.0001
	Percentage of non-western minorities	0.2890	<0.0001
NO_2 pavement	Average income per inhabitant	**0.4243**	**<0.0001**
	Average income per income recipient	0.2879	<0.0001
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	0.3672	<0.0001
	Percentage of people with a certain income level (high, mid, low)	0.2907	<0.0001
	Percentage of non-western minorities	0.2567	<0.0001
Available public green areas within 200 m	Average income per inhabitant	0.0605	0.0454
	Average income per income recipient	0.0619	0.0422
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.2102**	**0.0001**
	Percentage of people with a certain income level (high, mid, low)	0.1422	0.0019
	Percentage of non-western minorities	0.0222	0.1333
Available public green areas within 500 m	Average income per inhabitant	0.0754	0.0207
	Average income per income recipient	0.0919	0.0085
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	0.0415	0.1966
	Percentage of people with a certain income level (high, mid, low)	**0.1612**	**0.0016**
	Percentage of non-western minorities	0.0676	0.0080
Available public green areas within 1000 m	Average income per inhabitant	0.0956	0.0069
	Average income per income recipient	0.0954	0.0070
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	0.1021	0.0307
	Percentage of people with a certain income level (high, mid, low)	**0.1618**	**0.0006**
	Percentage of non-western minorities	0.0949	0.0016
Dwellings with a safety risk contour	Average income per inhabitant	0.0310	0.2108
	Average income per income recipient	0.0557	0.0587
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.0787**	**0.0874**
	Percentage of people with a certain income level (high, mid, low)	0.0513	0.1623

Environmental indicator (outcome)	**Socio-economic indicator: income**, defined as:	**R^2**	**p-value**
	Percentage of non-western minorities	0.0130	0.2518
Presence of a waste disposal site within 250 m	Average income per inhabitant	0.0040	0.8187
	Average income per income recipient	0.0028	0.8695
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.0092**	**0.9223**
	Percentage of people with a certain income level (high, mid, low)	0.0029	0.9630
	Percentage of non-western minorities	0.0000	0.9549
Presence of a waste disposal site within 500 m	Average income per inhabitant	0.0086	0.6510
	Average income per income recipient	0.0089	0.6411
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.0122**	**0.8755**
	Percentage of people with a certain income level (high, mid, low)	0.0099	0.8092
	Percentage of non-western minorities	0.0040	0.5273
Presence of a waste disposal site within 1000 m	Average income per inhabitant	0.0124	0.5397
	Average income per income recipient	0.0139	0.5000
	Percentage of people of a certain income category (<30,30-50, 50-80, >80,000 guilders/year)	**0.0344**	**0.4849**
	Percentage of people with a certain income level (high, mid, low)	0.0200	0.5787
	Percentage of non-western minorities	0.0062	0.4294

APPENDIX 10 Correlation coefficients (Spearman) between income indicators and indicators of perceived environmental quality

- not weighted; n ≈ 60 -

	% with income < 30,000 guilders per year	**% with income > 80,000 guilders per year**	**% low income**	**% high income**	**Average income level per inhabitant**	**Average income level per inhabitant**
% perceiving air pollution as largest problem	-0.43[1] (<0.01)	0.49 (<0.01)	-0.36 (<0.01)	0.37 (<0.01)	0.30 (0.02)	0.39 (<0.01)
% perceiving malodour as largest problem	-0.29 (0.03)	0.36 (<0.01)	-0.39 (<0.01)	0.43 (<0.01)	0.48 (<0.01)	0.45 (<0.01)
% perceiving traffic as largest problem	-0.32 (0.01)	0.52 (<0.01)	-0.45 (<0.01)	0.46 (<0.01)	0.49 (<0.01)	0.51 (<0.01)
% perceiving safety risks as largest problem	0.01 (0.95)	-0.01 (0.93)	-0.15 (0.26)	0.08 (0.55)	0.18 (0.17)	0.10 (0.44)
% not satisfied with amount of green areas in neighbourhood	0.54 (<0.01)	-0.41 (<0.01)	0.32 (0.02)	-0.40 (<0.01)	-0.33 (0.01)	-0.39 (<0.01)
% not satisfied with quality of green areas in neighbourhood	0.49 (<0.01)	-0.43 (<0.01)	0.47 (<0.01)	-0.56 (<0.01)	-0.55 (<0.01)	-0.55 (<0.01)
% often annoyed by noise in neighbourhood	0.52 (<0.01)	-0.55 (<0.01)	0.51 (<0.01)	-0.58 (<0.01)	-0.59 (<0.01)	-0.58 (<0.01)

[1] correlation coefficient
(p-value)

APPENDIX 11 Correlation coefficients (Spearman) between ‘ objective’ environmental indicators and indicators of perceived environmental quality

- not weighted; n ≈ 60 -

A. Noise:

	Average accumulated noise level	Average railroad traffic noise level	Average aircraft noise level	Average road traffic noise level
% often annoyed by noise in neighbourhood	-0.32[1] (0.01)	0.19 (0.15)	-0.66 (<0.01)	-0.47 (<0.01)
% perceiving traffic as largest problem	0.45 (<0.01)	0.25 (0.05)	0.22 (0.09)	0.43 (<0.01)

B. Air pollution

	Average NO_2 level at the front	Average NO_2 level at the pavement
% perceiving air pollution as largest problem	-0.14 (0.30)	-0.16 (0.22)
% perceiving malodour as largest problem	-0.08 (0.56)	-0.09 (0.48)
% perceiving traffic as largest problem	0.19 (0.16)	0.21 (0.12)

[1] correlation coefficient (p-value)

C. Public green areas:

	Average m^2 of available public green areas within 200 m	**Average m^2 of available public green areas within 500 m**	**Average m^2 of available public green areas within 1000 m**
% not satisfied with amount of green areas in neighbourhood	-0.36 (<0.01)	-0.47 (<0.01)	-0.60 (<0.01)
% not satisfied with quality of green areas in neighbourhood	-0.40 (<0.01)	-0.46 (<0.01)	-0.59 (<0.01)

D. Safety risks:

	% dwellings within safety risk contour
% perceiving safety risks as largest problem	0.26 (0.05)

APPENDIX 12 Mailing list

1. C.M. Plug, LMV, DGM, VROM
2. J.A. Verspoor, LMV, DGM, VROM
3. M. van den Berg, LMV, DGM, VROM
4. A. Bezemer, IPC, DGM, VROM
5. J.J. de Boer, IPC, DGM, VROM
6. F. Rerhioui, DGR, VROM
7. W. Bringmann, GSB, BZK
8. R. van Aalst, European Commission DG Environment
9. M.J.W.Sprenger, DG RIVM
10. F. Langeweg, DMN, RIVM
11. N.D. van Egmond, DMN, RIVM
12. R.D.Woittiez, SME, RIVM
13. A. Jones, University of East Anglia, UK
14. I. Bateman, University of East Anglia, UK
15. J. Brainard, University of East Anglia, UK
16. M. Buzzelli, University of British Columbia, Canada
17. R.W. Marans, University of Michigan
18. H. Keune, University of Antwerp
19. P. Glasbergen, Universiteit Utrecht
20. P.J.J. Driessen, Universiteit Utrecht
21. V. Schutjens, Universiteit Utrecht
22. R. van der Wouden, RPB
23. V. Veldheer, SCP
24. F. Knol, SCP
25. F.Woudenberg, GGD Rotterdam
26. I. Walda, GGD Rotterdam
27. R. Spoel, DCMR
28. H.de Bruijn, Stadsregio Rotterdam
29. L. de Haas, dS+V
30. E. van Heijningen, Provincie Zuid-Holland
31. H.M.E. Miedema, TNO-Inro
32. E. Agricola, KEI Kenniscentrum Stedelijke Vernieuwing
33. P. Ester, Institute for Globalization and Sustainable Development
34. International Institute for the Urban Environment
35. P. Kuenzli, Gideon Consult BV
36. F. Coenen, CSTM, TU Twente
37. E. Maris, Rijksuniversiteit Leiden
38. A. Kunst, Erasmus Universiteit
39. P. Leroy, NSM, Katholieke Universiteit Nijmegen

40. P. Schildwacht, DSO, Gemeente Utrecht
41. E. Lebret, hMGO, RIVM
42. A.E.M. de Hollander, VTV, RIVM
43. A.J. Schuit, VTV, RIVM
44. M. Kuijpers, RIM, RIVM
45. L. Crommentuijn, RIM, RIVM
46. H. Diederen, LOK, RIVM
47. T. Dassen, LOK, RIVM
48. F. Filius, LOK, RIVM
49. P. Lagas, LOK, RIVM
50. E. Hermans, LOK, RIVM
51. H.B.M. Hilderink, LOK, RIVM
52. A.J.M van Loon, PZO, RIVM
53. C. van Hooijdonk, PZO, RIVM
39. P.C.A. Droomers, PZO, RIVM
54. R. van Poll, MGO, RIVM
55. I. van Kamp, MGO, RIVM
56. J.M.H. Ruysbroek, MGO, RIVM
57. B.A.M. Staatsen, MGO, RIVM
58. R. Stellato, MGO, RIVM
59. J.C.M. Köhler, MGO, RIVM
60. Auteurs

SBC/Communicatie
Bureau Rapportenregistratie
Depot Nederlandse Publicaties en Nederlandse Bibliografie
(1) Bibliotheek RIVM
(5) Bureau Rapportenbeheer
Reserve exemplaren