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Representativeness and classification of air quality monitoring stations

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SUMMARY

Concept, Objectives and Motivation

The main objectives of the project „Development of the methodologies to determine representativeness and classification of air quality monitoring stations“ are to develop definitions, methods and validation procedures for

- the classification for air quality (AQ) monitoring sites for various pollutants, focusing on NO_2, PM10 and ozone, but also taking into account PM2.5, SO_2, NO_x, CO and benzene;
- the assessment/delimitation of the geographical area of representativeness of air quality monitoring sites.

The definitions and the methodology take into account the following principles:

- The methodology should be applicable throughout Europe.
- Both classification and representativeness provide results specific to different pollutants.
- Classification and representativeness are temporally constant over time periods of at least several years. The area of representativeness of a monitoring station does not vary e.g. in a daily, weekly or annual cycle or due to different meteorological conditions.
- Classification and representativeness may vary in the long term, e.g. due to changes in emissions.
- Since future AQ monitoring stations can be situated at different points in space, the classification methodology developed in this study focuses not only on existing monitoring stations, but considers any point in space in Europe.

The central motivation for developing a „new” classification approach is a desire to improve the description and classification of monitoring stations used for air quality reporting and data analyses on a European level. The classification method developed and proposed in this study can be used to improve the monitoring station description as required by EC legislation, especially in the Exchange of Information Decision (101/97/EC).

The primary advantages of the proposed classification method which could improve the EoI station descriptions are:

- **it gives quantitative criteria (though not for all emission categories),**
- **it is uniformly applicable throughout Europe,**

which should allow a more accurate description of monitoring stations with respect to emissions, and harmonise meta-information about monitoring stations throughout Europe. Unlike the EoI station descriptions, the proposed classification is pollutant-specific.

The central purpose of classification is to facilitate statistical analyses of data by grouping monitoring sites into classes with common characteristics. Emissions from different major source categories are a traditional basis for monitoring site classification, and this approach has also been pursued in this study. Emissions are an external parameter influencing air quality; other approaches based on the measurement data itself, like characteristics of daily variations or ratios between pollutants, may also be applied alternatively.

The assessment of the representative area of a monitoring station allows extending information observed at one point – the monitoring site – to the area of representativeness. Within this area, concentrations deviate – within a certain range – from the measured concentration at the respective monitoring site, for which proposals are given in this study, – and additional criteria have to be fulfilled, based on „common reasons” – like emissions and the dispersion situation – for the measured concentration. Other ways to obtain spatial information are modelling and different kinds of expert estimation; in fact, both are proposed as inputs for representativeness assessment in this study.

Concept of Classification

Classification is a key instrument for the **interpretation and assessment of AQ data**, especially for large data-sets covering large areas with a wide variety of types of locations, as handled by international organisations such as the EEA and its Topic Centre on Air and Climate Change.

Classifying AQ monitoring stations is achieved by creating groups of monitoring sites with common characteristics which may, depending on the classification scheme, provide the following information:

- Information about (various) local sources of air pollution (in addition, information on regional scale background concentrations, and dispersion conditions could be included).
- Information about affected receptors such as humans (related to exposure).
- Support of spatial AQ assessment, including determination of the area of representativeness.

The classification scheme developed in this study – focussed on NO_2/NO_x and PM10 – is based upon **emissions** and takes into account the **three most important source categories**: **Local road traffic**, **domestic heating** and **industrial and commercial sources** (including power plants, and special infrastructural facilities like airports or ship emissions in large sea ports and harbours). The impacts of each source category to a monitoring station are estimated independently from each other.

The classification scheme proposed can be applied for **primarily emitted pollutants** and is **specific to each pollutant**. The classification scheme is an extension of the „type of station" classification in the EoI meta-data (97/01/EC).

The classification scheme is based upon an estimation of the absolute contribution of each source category to the concentration level observed at the monitoring station. In this context it should be noted that the absolute contribution of different source categories may differ widely – for example, NO_x originates predominantly from road traffic in most cities, and even at a monitoring site classified under „low traffic influence" and „high domestic heating influence", the absolute contribution from road traffic is likely to exceed the absolute contribution from domestic heating.

The classification method is based on an assessment of the impact of local road traffic and domestic heating – by considering the amount and distance of emissions – and does not use measured or model data, or data on source apportionment (which are used for validation of the classification method in this study). The classification scheme also includes industrial and commercial sources. However, for these, no simple, generally applicable method based on surrogate data to estimate the contribution can be provided. Therefore, application of modelling or expert estimates is recommended.

The classification scheme does not cover emissions from sectors other than the ones mentioned above. Consequently, sectors such as off-road machinery, agriculture, and natural PM sources are not included. These sources are less relevant from a European perspective than the three main source categories.

The regional PM concentration level is proposed as an optional fourth classification parameter (besides local road traffic, domestic heating and industrial/commercial sources).

Classification parameters

The classification parameter for **local road traffic** is an estimator for the contribution from local road traffic to the concentration at a given site.

Local road traffic is taken into account since total road traffic emissions (on a wider spatial scale), which usually cover more than 50 % of total (urban) NO_x emissions, also provide the predominant contribution to background concentrations. The focus on local road traffic emissions is further justified because road traffic emissions have a very distinct spatial variability, and local road traffic emissions affect locations near the road to a largely different extent compared to locations far away from roads.

The contribution of road traffic emissions is referred to as „traffic emission parameter” and is quantified by the following approximation:

Traffic emission parameter = **emissions of local road traffic divided by square root of the distance**

The square root of the distance from the road as the denominator is the best simple mathematical approximation for the concentration distribution along a street from model results.

The distance should be measured from the kerb of the road to the air inlet. For motorways and main roads, the distance should be measured from the edge of the first lane (not from the hard shoulder).

Especially in urban locations, monitoring sites may be located quite close to major roads, but shielded from the road by compact buildings and therefore not much affected by traffic emissions (or only to a minor extent). Based on model results, an **„exposure coefficient”** is introduced, by which the respective traffic emissions are to be multiplied. The exposure coefficient is assumed to be **0** for the configuration of a monitoring site and a road with completely closed building blocks in between (which means that in such cases, nearby traffic emissions do not contribute to the measured pollution), **0.5** for buildings with small gaps or a monitoring site located in a narrow side lane, **1** for free air flow between road and monitoring site in open terrain, and **1.5** for situations with adverse local dispersion in street canyons.

The contribution of **domestic heating emissions** to the ambient air concentration may be assessed by modelling or by using surrogate parameters. The classification method discussed in this study can be applied if modelling is not available. It considers the domestic heating **emissions within a radius of 1 km.**

The contribution of **industrial (commercial) emissions** can either be assessed by modelling or by expert judgement. There is no simple, generally applicable way to assess the industrial contribution using surrogate information, since industrial sources cover a wide range of different configurations regarding e.g. spatial distribution and the number of sources (single stack vs. fugitive emissions) of a certain plant as well as the vertical height of emissions; further external parameters are dispersion and wind conditions.

The application of the classification scheme is demonstrated and tested in this study with three classes for each emission category.

As a definition of „**urban background**”, locations which have been put into the lowest class related to road traffic and industry are proposed. **Rural background** shall cover locations which have been put in the lowest class regarding all categories of emissions.

Ozone

Ozone is a secondary pollutant; formation and depletion processes are used for classification. Classification of ozone monitoring sites is based upon the following parameters:

- Local ozone depletion by NO titration is taken into account by classification of **NO_x emissions from local road traffic**; two classes are proposed.
- The effect of ozone depletion at the surface and vertical mixing, leading to a distinct vertical gradient, is dealt with by a simple topographic classification based on **exposure**: „plain” for low vertical exchange and high surface depletion; „mountain” for good vertical exchange and low surface depletion; „high alpine” for locations on high mountain summits characterised by strong exchange with the free troposphere and negligible surface depletion.

- **Regional photochemical ozone formation** in the plumes of large agglomerations can be assessed either by expert judgement or through assessment of regional NO_x and VOC emissions within a circle of approx. 50 to 100 km in radius; two classes are proposed.

Classifying AQ monitoring sites **according to the population distribution** separates different types of urban and rural sites. The proposed classification scheme is in principle related to the „type of area" description used in the Ozone Directive (2002/3/EC) and the Exchange of Information Decision (97/101/EC).). In this study, a similar, but distinct approach is suggested.

The proposed criteria are based on a combination of population numbers within a radius of 1 km and 10 km. A radius of 1 km refers to local emissions, whereas a radius of 10 km covers also medium-range transport and pollutant accumulation. This scheme can be used both for exposure assessment and assessment of total emissions, since the population density is a surrogate value for spatially distributed emissions.

The population within a radius of 10 km separates the following types of area: remote area, rural area, urbanised area, large city area. These areas are subdivided according to the population number within a radius of 1 km, resulting in a total of 8 classes.

Test of the classification method

The classification method was tested using NO_2, PM10 and ozone monitoring stations mainly in Austria, but also in the Netherlands. For each of the three emission categories – local road traffic, domestic heating and industry – three classes were set up. The class boundaries were selected based upon the distribution of the classification parameter for local road traffic and domestic heating; industrial sites were classified into the classes „low" and „medium" using model results and estimates from various sources.

For each class, average NO_2 concentrations of all Austrian stations falling into the respective class are determined. It is shown that average NO_2 concentrations are clearly related to the classification according to local road emissions. The relation of the NO_2 concentrations to the classification according to domestic heating emissions is less distinct than might have been expected; the „medium class" and the „high class" of domestic heating differ only slightly. This might be due to the fact that traffic emissions exert a major influence on urban NO_2 concentrations. In the sub-class „low traffic", there is a clear relation between average NO_2 concentrations and the domestic heating classification.

Average NO_2 concentrations show no relation to the classification according to industrial emissions; the influence of these is superseded mainly by traffic contributions. Only in the sub-class „low traffic", and for all three classes of domestic heating emissions, NO_2 concentrations are related to the industrial emission classification.

Comparing these classification results with the **„type of station" classification** according to the Exchange of Information Decision (97/101/EC) for Austria shows quite a good relation between „traffic stations" according to EoI and the class „high" for NO_2 according to the traffic emission parameter defined in this study.

However, some distinct differences have been detected. One of the most striking examples of different classification is the Austrian monitoring site Wald am Arlberg in the immediate vicinity of the S16 motorway, which has been classified as a „traffic" site according to EoI, although the emissions measured on this motorway with only 10,000 vehicles per day give a classification of „low traffic influence".

On the other hand, several suburban sites in the agglomeration of Wien (e.g. Laaerberg) and Linz (Kleinmünchen) have been classified as „background" site according to EoI. The assessment of road traffic emissions in the larger vicinity of such stations shows a considerable traffic influence from motorways up to a distance of more than 0.5 km, which is not considered by only assessing the potential influence of local roads.

Some sites are classified according to the EoI classification scheme as **industrial**, while there are no indications for a significant influence of industrial emissions on NO_2 and PM10 levels. The **EoI classification is not pollutant-specific**, and the classification „industrial" is often attributed to SO_2 and heavy metal emissions which do not correlate with NO_x and PM emissions.

Definition of Representativeness

Directive 96/62/EC requires the assessment of air quality **throughout the territory** of the Member States of the European Union. Since monitoring stations are point measurements, supplementary methods for assessing air quality in the whole area are necessary.

The task of the assessment of **representativeness** is aimed at the delimitation of areas of the concentration field with **similar characteristics** at specific locations. Characteristics, the similarity of which is being investigated, can either be concentration levels, (statistical) properties of the measured AQ data, or external parameters influencing AQ, like emissions and dispersion conditions. Representativeness in this study is related to annual limit/target values laid down in EC legislation. It does not refer to information or alert values related to shorter time scales (one, eight hours); quite different methods would be necessary to estimate the representative areas on such low time scales, with a much higher spatial variability.

In this study, the general definition of representativeness is based on the following two criteria:

- The concentration parameter (annual mean and annual percentile) is below a certain threshold.
- The „similarity of concentrations" is caused by common external factors.

The proposed **numeric threshold values** for averages and percentiles are set at 10% of the total range of values observed in Europe. This means that the total observed concentration range is separated into 10 classes. Based on the whole European data set (AirBase) of NO_2, PM10 and ozone for the years 2002 to 2004 (excluding some extremely high PM10 values in FYR Macedonia) the concentration range observed in Europe (i.e. EU27) provides in the following concentration thresholds:

- **NO_2: Annual mean value at the monitoring station ± 5 µg/m³**
- **PM10: Annual mean value at the monitoring station ± 5 µg/m³**
- **PM10: Annual 90.4 percentile of daily mean values at the monitoring station ± 8 µg/m³**
- **Ozone: annual 93.2 percentile of daily maximum 8-hour mean values at the monitoring station ± 9 µg/m³**

In order to avoid „similarity by chance" in one year, but not in another year – due to e.g. interannual variations of meteorological conditions – the criterion has to be fulfilled over three years.

For **NO_x** (which covers a concentration range of more than 300 µg NO_2/m³), a range of 10% of the total concentration range observed in Europe is not useful. NO_x is of relevance only at monitoring sites where the limit value for the protection of vegetation and ecosystems applies, namely locations rather remote from NO_x sources with quite low concentration levels, which exceed the limit value only in rare situations. Therefore it is proposed that for **NO_x** the same range should be used as for NO_2.

Generally it has to be kept in mind that the numeric values for the thresholds used for the assessment of representativeness are, in any case, arbitrary. Choosing different numeric threshold values will lead to larger/smaller classes and areas of representativeness.

The second criterion – „**similarity for common reasons**" – is included in the definition, because similar annual mean values or percentiles can be observed by chance at different locations due to a combination of quite different external factors like emissions, dispersion, long-range transport, formation or depletion.

Therefore, the following external parameters are used as criteria for delimitation of the area of representativeness:

- **Emissions** from different types of sources (the three categories on which the classification scheme is based are used).
- **The climatic and topographic dispersion situation,** including local **building structure**.
- A **maximum extension** of the area of representativeness, related to transport and chemical transformation in the atmosphere.

The dispersion situation in this context is related to the **climatic and topographic situation** and the local **building structure/street geometry** which trigger the dispersion/accumulation of pollutants. They cover different scales:

- **Local environment**: Scale < 100 m (street geometry, local building structure and topographic situation, forest)
- **Regional environment**: Scale < 10 km (valleys, basins, flat terrain, coastal areas etc.)
- **Large-scale**: > 10 km (large-scale topographic and climatic region)

We propose separating the following types of „local environment" for kerbside locations (and perhaps for industrial locations), where the dispersion of local emissions is a key factor for the local pollution level: street canyons; one-sided compact buildings; detached buildings; flat terrain; exposed location. For background sites, a separation of built-up area and flat terrain is considered sufficient.

For the „regional environment", the different types of flat, hilly, mountainous and costal terrain are to be separated.

The large-scale topographic/climatic units cover e.g. the Alps north and south of the central ridge, the Po Valley, the Pannonian Plain, the Bohemian Massif, or the German Mittelgebirge.

The chemical transformation – i.e. both removal and formation – of the major pollutants considered in this study (NO_2, PM10, ozone) covers a temporal scale of less than one day (average atmospheric lifetime of about 12 h for NO_2). The corresponding distance is considered the **maximum extension** of the area of representativeness of a monitoring station. For the extra-Alpine parts of Austria, the respective distance is about 100 km, derived from an analysis of backward trajectories.

Assessment of Representativeness

To determine the pollutant concentration at all points in space, there are, in principle, two possibilities:

- Determining the pollutant concentration using air quality modelling;
- Determining the pollutant concentration based on surrogate data which are spatially available themselves. The assessment of the concentration distribution based on surrogate data, often called parameterisation, can in fact be referred to as a simple modelling technique.

Input data for the parameterisation of concentrations are **emission data** (emission densities) or **surrogate data for emissions** (such as traffic information or population density) and parameters triggering **dispersion** (meteorological or climatological data, topographical/geographical information, building structure, etc.). These data also serve as input for modelling.

Different methods have been developed for the **assessment of concentrations based on surrogate data**, covering different levels of sophistication - from using land-use information to simple modelling techniques. Such assessment methods can also be used to estimate emissions. The testing and validation process in this study uses a simple empirical relation between measured concentrations and the following basic geographical information to estimate both concentrations and emissions:

- Topography
- CORINE Landcover
- TeleAtlas functional road classes
- Population per municipality

This simple method, however, can only be applied to rural and small-town locations, with only a coarse representation of traffic influence. For urban areas, much more precise information about both emissions and concentration patterns is essential.

Validation of the assessment of representativeness

For validation of the method for representativeness assessment, monitoring stations and model results from Austria, the Netherlands and England are used.

The most thorough validation is performed for Austria. It is shown that the representativeness criteria for ozone works well for delimitating rural areas at different elevations.

Without model data which give a detailed picture on the spatial variability of concentrations, those parameters which are used to assess the other external factors determining concentration – emissions and the dispersion situation – are used as a surrogate. A first attempt to assess the representative area for NO_2 monitoring sites in Wien gives reasonable results, using the quite detailed emission inventory for this agglomeration.

For the EMEP site Illmitz (rural background), situated in flat terrain, the topographic map, TeleAtlas street types and built-up areas are used as surrogate information to exclude areas with higher emissions and elevated terrain from the area of representativeness.

Additionally, representative areas were checked using data from a NO_2 passive sampling study, and concentration criteria for the area of representativeness were subjected to a sensitivity analysis.

To summarise, the results of the validation suggest that the proposed threshold values, in combination with the criteria for common reasons for similar concentrations, allow a practicable delimitation of representative areas.

Further Development

The classification scheme proposed in this study can be used, as stated above, to expand the description/classification of monitoring stations – „type of station" – according to EoI. We propose that the new classification scheme should be considered in the Implementing Provisions on reporting for the revised Air Quality Directive. The main advantage of the new classification scheme is that it gives quantitative criteria (though not for all emission categories) and it is therefore uniformly applicable throughout Europe.

The classification scheme proposed in this study should be tested in additional countries to those used in this study by monitoring network operators who have a detailed knowledge of the location of their monitoring stations as well as access to the necessary emission data.

The „type of area" – which may be urban, suburban, and rural – could also be revised according to the proposals of this study. Chapter 3.3 presents a first approach for the classification of monitoring sites according to population distribution, related to the „type of area" in EoI, but more refined with many more classes. This classification scheme for population distribution should be tested, using population data from various countries.

In principle, the classification scheme proposed in this study is compatible with the present EoI „type of station" description, retaining the basic classes „traffic", „industrial" and „background"; the class „unknown" should be removed. The main technical change concerns the shift of classification from the station level to the pollutant level („measurement configuration" in the Data Exchange Module).

At present, the station description/classification according to EoI is static, without reference to a certain year. Updates are not documented, and neither is the status in earlier times. Any classification can, however, change due to changes in the emissions on which it is based, e.g. by constructing new roads or by abatement measures at certain industrial plants.

Further developments of reporting on meta-information should therefore include

- giving the reference year of the station description/classification,
- updating (periodically) the station description/classification,
- and possibly a history of the station description/classification.

The approach for determining the representative area presented in this study should be applied in test cases and continuously developed, evaluated and harmonised, based on the experience gained.

Different procedures using different input data sets should be pursued and evaluated. The following levels of input data have to be compared:

- model data, emission inventories and information on the local dispersion situation available
- no model data, but emission inventories and information on the local dispersion situation available; the spatial concentration distribution has to be assessed by surrogate information (emissions and dispersion situation)
- no model data and no emission inventories are available; the spatial concentration distribution and the distribution of emissions have to be assessed by surrogate information (land use data, e.g. CorineAir, road information, e.g. TeleAtlas roads, topographic information).

The method should be tested in various parts of Europe with different climatic and topographic conditions, in order to evaluate, refine and revise the classification of the regional and large-scale dispersion situations. Close cooperation between the respective AQ monitoring network operators, the team which has developed this study, EC and EEA seems necessary. Financing of appropriate projects should be discussed. In order to achieve international comparability of datasets and facilitate the development of joint services under GEOSS, comparability with the approaches taken in international networks, in the USA, etc. should be monitored.

1 INTRODUCTION

1.1 Concept and Objectives

The main objectives of the project ”Development of the methodologies to determine representativeness and classification of air quality monitoring stations“ are to

- obtain a set of validated methodologies to classify monitoring stations and to
- quantify the respective representative areas.

The objectives of the present study are to develop

- definitions,
- methods and
- validation procedures for
  - the classification of air quality (AQ) monitoring sites for various pollutants (focusing on NO_2, PM10/PM2.5 and ozone, but also taking into account SO_2, NO_x, CO, benzene, and heavy metals);
  - the assessment of the geographical area of representativeness of air quality (AQ) monitoring sites.

This will include – as basic information for both purposes – a proposal for parameters for a more comprehensive description of monitoring stations (meta-information).

The definitions and the methodology take into account the following principles:

- the methodology should be applicable throughout the EU27 territory (and to the whole EEA territory);
- the main pollutants to be dealt with are NO_2, NO_x, PM10/PM2.5 and ozone; but it shall be ensured that the method can be applied to all pollutants;
- both classification and representativeness provide results specific to different pollutants;
- the methodology refers to the near-surface concentration, i.e. to a two-dimensional concentration field. The vertical pollutant distribution – and measurements at elevated locations like towers – will not be dealt with.
- classification and representativeness are temporally constant over time periods of at least several years;
- classification and representativeness may vary in the long term, e.g. due to changes in emissions. The concept that representativeness is constant over time periods of at least several years means in fact that the area of representativeness of a monitoring station does not vary e.g. in a daily, weekly or annual cycle or due to different meteorological conditions.
- Since AQ monitoring stations could be situated at any type of location, the classification methodology developed in this study does not only focus on existing monitoring stations, but considers all types of locations which can be found in Europe.

The task of the classification of air quality monitoring stations and the assessment of their representativeness can – in a broader sense – be addressed as the delimitation of areas where air pollution has **similar characteristics**.

Classification of monitoring stations can be addressed as a sub-task of the assessment of similar characteristics restricted to the locations where monitoring sites are operated. Classification of AQ monitoring stations means to put locations into a group with common characteristics, separating them from groups with other common features.

The main purpose of classification is to support data interpretation.

The task of the assessment of **representativeness** aims at the delimitation of areas of the concentration field with similar characteristics at specific monitoring stations.

Characteristics, the similarity of which is being investigated, can either be concentration levels, (statistical) properties of the measured AQ data, or external parameters influencing AQ, like emissions and dispersion situation.

Besides being representative of a certain area, a monitoring station may also be representative of a certain situation, e.g. representative of exposure of the general population, or representative of the effects of highway traffic etc. Ifn that is the case, data from such a station can give information on the effectiveness of measures. In the present report, the focus lies on representative areas rather than on other factors, but the representative areas are determined taking into account factors such as traffic volume.

Any parameter for the assessment of representativeness (either statistical properties or external parameters) can, of course, yield different areas of representativeness (a) on different time-scales and (b) for different time periods. Periodic variations both of emissions (daily, weekly, annually) and of meteorological parameters (daily, annual variations of temperature and dispersion situation; periodic thermotopographic circulation systems) as well as random variations of meteorological conditions (synoptic scale situations) influence, of course, the area of representativeness.

Anyhow, it is considered too difficult to set up a „dynamic” methodology for an assessment of representative areas which considers the temporal variation (either periodic or random) of external influencing parameters. Therefore the methodology for an assessment of representativeness will yield a „static” area of representativeness.

The assessment of the area of representativeness of a monitoring station can be an important input for the spatial representation of concentration values.

1.2 Difficulties of current classification schemes and methods for representativeness assessment

Currently applied classification schemes are mainly based on a selection of parameters from meta-information on monitoring stations – i.e. the description of the surroundings of the monitoring station, focusing on emissions and population distribution, as e.g. implemented in the EoI (97/101/EC). This meta-information itself comprises „classifications” of areas, e.g. residential, commercial, industrial/residential, …, or „urban”, traffic”, …

The main shortcomings of many common classification schemes are

- the heterogeneity of available information (and of its reliability) throughout Europe;
- the lack of quantitative criteria for different classes.

An assessment of the representative area of a monitoring site is usually performed by expert estimation, based on more or less semi-quantitative assessments of parameters influencing the pollution level like emissions, population distribution, land use and the topographic situation.

1.3 Limitations of methods for the classification and assessment of representativeness

The development of methods for the classification and assessment of representativeness has to deal, within the framework of the service contract, with NO_2, NO_x, PM10, PM2.5 and ozone. Nevertheless, the methods should be applicable to all pollutants.

The study focuses on NO_2, PM10 and ozone. For **NO_x**, the same classification and representativeness criteria are proposed as for NO_2. NO_x concentrations are legally relevant at locations remote from towns and major streets – to check compliance with vegetation limit values –, where NO_x levels are low and NO levels very low. This justifies the limitation of methods for the classification and assessment of representativeness to fairly low NO_x concentrations. The low NO/NO_x ratio justifies treating NO_x in this concentration range similarly to NO_2.

PM2.5 will not be treated specifically. The **PM2.5** measurements available in Europe in the few last years are not sufficient to test and validate methods for the classification and assessment of representativeness. The quite narrow range of PM2.5/PM10 ratios observed on an annual basis in Europe (except situations with high contributions by Saharan dust) justifies treating PM2.5 similarly to PM10.

Generally it has to be kept in mind that the numeric values for the thresholds used for the classification and assessment of representativeness are, in any case, arbitrary to some extent. Choosing different numeric threshold values will lead to larger/smaller classes and areas of representativeness.

Regarding micro-scale siting of monitoring stations, the following limitations have to be considered:

- Methods for the classification and assessment of representativeness shall be applicable on any near-ground location in Europe which fits the siting criteria for AQ MS laid down in the AQ Directives.
- The methods will not be applicable for locations on top of towers or high buildings.
- The methods will not be applicable for locations with no free air flow (i.e. locations closely surrounded by trees or buildings).

With respect to the temporal scale of one year of the concentration values which will be the basis of the assessment of representativeness,

- representativeness is related to annual limit/target values. The shorter-term temporal variability is considered by taking the dispersion situation into account; nevertheless no explicit criteria for representativeness on a time-scale of hours are developed;
- therefore, representativeness as defined in this study does not refer to information or alert values, for the exceedance of which the area of representativeness may be much smaller.

Classification and representativeness are considered constant over time. In order to take the inter-annual variation of meteorological conditions into account, data from several years (recommended: 3 years) is used.

On the other hand, changes in emissions or local building structure may change classification and representativeness. Therefore, a re-calculation of classification and assessment of representativeness after some years is recommended.

1.4 Applications and purposes of classification of AQ monitoring stations

Any classification of AQ monitoring stations creates groups of monitoring sites with common characteristics.

Classification is a key instrument for the **interpretation and assessment of AQ data** – especially for large data-sets covering large areas with a wide variety of types of locations – providing the following information (see chapter 1.5):

- Basic information about (different) causes/sources of air pollution (primarily emissions, but possibly also dispersion situation) (chapter 1.5.4);
- Basic information about the affected receptors such as humans (related to exposure) (chapter 1.5.2);
- Support of spatial AQ assessment, including the determination of the area of representativeness (chapter 4).

International organisations such as the EEA and its Topic Centre on Air and Climate Change are faced with the challenging task to **interpret data from a large number of monitoring sites** without knowing the special peculiarities of all sites. In order to support a meaningful interpretation, classification (together with other meta-information) is an important tool.

AQ assessment means the analysis of AQ data, including its interpretation and the investigation of causes of air pollution (chapter 2.2). For AQ assessment over large areas – e.g. the whole of Europe – it is necessary to structure the information which is available from a very large number of monitoring stations and might also include model results of other assessment methods.The classification of monitoring stations is a key component of structuring spatially wide-spread information and making AQ data comparable over large areas.

1.5 Applications and purposes for the assessment of representativeness of AQ monitoring sites

Several applications require spatial information about AQ. Therefore, methods for an „extension" of measured AQ information to the territory are necessary, and are given in Table 1.

The present study deals with monitoring networks which are mainly run for compliance assessment and for the information of the public. Monitoring stations or networks for scientific purposes are not taken into account.

Table 1: Applications of spatial information on air quality.

Purpose	Motivation
Compliance assessment based on data from monitoring stations (chapter 1.5.1)	Delimitation of areas where limit or target values (incl. margin of tolerance) are exceeded or not
Exposure assessment (human health, ecosystems, specific plant species …) (chapter 1.5.2)	Estimation of effects of a pollutant
Information of the public (chapter 1.5.3)	Delimitation of areas with homogeneous concentrations with respect to the relevant limit/threshold/alert values, including maps
Analysis of causes of air pollution: Emissions, dispersion situation, atmospheric chemistry, deposition, … (chapter 1.5.4)	Delimitation of areas where AQ is influenced/triggered by similar parameters – emission sources (i.e. with similar temporal variations and triggered by common legal regulations) and other similar influencing factors – important for the development of abatement measures
Model validation and **input** (chapter 1.5.5)	Selection of monitoring stations representative of geographical areas related to the spatial model resolution; data assimilation.
Monitoring network design (chapter 1.5.6)	Identification of geographical areas which are not sufficiently covered by monitoring stations or which are covered by several redundant monitoring stations The monitoring network design serves the other purposes listed above.
Assessment of representativeness (chapter 1.5.7)	Spatial information on air quality

1.5.1 Compliance assessment

Directive 96/62/EC requires the assessment of air quality throughout the territory of Member States of the European Union. Since monitoring stations are point measurements, methods for assessing air quality for the whole area are necessary.

Assessing the representativeness of the monitoring sites provides those areas for which monitoring data can be – more or less – extrapolated. „Compliance assessment throughout the territory" is one of the core objectives, attributing monitoring results to areas with no measurements.

Compliance assessment has to focus on the **absolute pollution level** in relation to the limit or target value.

Assessing the spatial representativeness of monitoring stations can, of course, be performed by **modelling**. Other methods are the use of **passive sampling** networks – which only give long-term mean values – and the application of **surrogate data.**

Modelling – preferably in combination with measurements which, at least, are used for the calibration of the model – is a method for assessing air quality spatially. The objective „throughout the territory" is limited by the spatial resolution of the model.

1.5.2 Exposure assessment

Assessment of representativeness as a basis for **exposure assessment** requires the **delimitation of representative areas** in order to

1. determine which monitoring station is representative of certain receptors – taking into account that the receptors are not necessarily situated adjacent to the monitoring site;

2. gain information on which monitoring sites have to be used for the exposure assessment in a certain area;
3. classify areas with homogeneous (similar) exposure.

Exposure assessment may be used to quantify the impact of air pollution on different receptors including humans, crops and natural ecosystems. Exposure assessment also has to take into account personal activity patterns.

Exposure assessment has to focus on the absolute pollution level and on the basis of the temporal resolution the limit or target value is defined for (e.g. hourly, daily, annual mean).

1.5.3 Information of the public

An assessment of the representativeness of monitoring stations aiming at information of the public has to answer the question: which monitoring station can be used for information of which part of the population?

Information of the public about air quality therefore has to be considered in close connection with the monitoring network design, but also with assessment of exposure and compliance assessment; the major difference is that information of the public usually deals with short-term concentrations in the range of one hour to one day. A specific case is ozone, where active information of the public is provided if certain thresholds are exceeded. The information to be provided includes the area where limit values or information/alert thresholds are exceeded.

Information of the public can comprise the presentation of **maps** which are based on monitoring and/or modelling data (and some interpolation routine, which may also include other input parameters). Creating maps requires information on which monitoring station is representative of which area – depending e.g. on topographic features or emission pattern.

Information of the public therefore has to focus both on the absolute pollution level as well as the temporal variation in respect of the scale of the respective limit value.

1.5.4 Causes of air pollution – parameters influencing AQ

Information about sources/causes of air pollution is also relevant for the whole territory providing inputs for the development of measures. Representative areas within which concentrations are influenced by certain emission sources (roads, industries) may therefore be of interest for the development of measures.

1.5.5 Model validation and model input

Measured air quality data are essential for the validation of air quality models, and are often used as input for models, e.g. as boundary or initial conditions or to estimate the background concentrations due to processes which are not simulated by the model („data assimilation”).

The spatial (and temporal) representativeness of measured AQ data has to be clearly related to the spatial and temporal resolution of the model. This means that for the purpose of validation as well as model input, monitoring stations have to be selected carefully and their representativeness has to be checked thoroughly. The procedure of data assimilation could be improved by selecting appropriate monitoring data.

The most comprehensive effort in respect of long-range trans-boundary air pollution transport has been the design and evaluation of the EMEP network (EMEP/CCC, 2003) For EMEP, the site must be located so that the measurements of air quality and the precipitation chemistry parameters are representative of a larger region. In order for a site to be representative, influences and contamination from local sources must be avoided.

COST Action 732 is devoted to the improvement and assurance of the quality of micro-scale meteorological models that are applied for predicting flow and transport processes in urban or industrial environments (COST ACTION 732, 2005). Data sets and procedures as a standard for model validation purposes are identified.[1]

When using measured air quality data for the validation of air quality models, information on the representativeness of the used monitoring sites is crucial. This problem is addressed e.g. in the "Action 13206 - Air Quality and Transport Modelling" (AIRMODE), which is currently carried out at the Joint Research Centre in Ispra.

1.5.6 Monitoring network design

The design of a monitoring network has to take into account the various tasks of AQ measurement including:

- compliance checking with limit, target or alert values throughout the territory, representative especially of certain receptors (human population, ecosystems) and at hotspot locations;
- exposure assessment;
- information of the public;
- trend assessment;
- model validation;
- scientific purposes.

The Framework Directive (FWD)'s requirement of compliance assessment throughout the EC territory requires in fact the „knowledge" of concentrations for the whole territory, which can, of course, not be obtained by (point) measurement alone. Therefore the assessment of the representativeness of monitoring stations can be considered as a step towards „spatial AQ assessment".

Representativeness assessment has to be based upon quantifiable criteria for representativeness/similarity of concentrations and should also provide information on the following questions:

1. Which areas are not sufficiently covered by AQ monitoring stations?
2. Which areas are covered by redundant AQ monitoring stations?

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[1] COST Action 732 is devoted to the improvement and assurance of the quality of micro-scale meteorological models that are applied for predicting flow and transport processes in urban or industrial environments (COST Action 732, 2005). COST Action entered into force on 16 February 2005 and will end on 31st March 2009. Data sets and procedures as a standard for model validation purposes are identified. Currently a test data set containing flow and dispersion data measured within an idealised urban roughness originating from the „Mock Urban Setting Test - MUST", a field test carried out on a test site of the US Army in the Great Basin Desert in 2001, is made available to the participants for the validation of micro-scale meteorological and dispersion models. COST Action will issue several documents like a Model Evaluation Guidance and Protocol Document and a Best Practice Guideline for the simulation of flows in the urban environment. A Background and Justification Document is at a finishing stage. The homepage of COST Action is http://www.mi.uni-hamburg.de/COST_732.464.0.html .

The area of representativeness may cover non-contiguous domains; e.g. the concentrations measured at a roadside monitoring station may be representative of the situation in another roadside area (or even another town) which is not directly adjacent.

The overall objective of air quality monitoring – i.e. of establishing and operating an air quality monitoring network – is to place monitoring stations in such a way that the concentration field across the whole territory may be analysed in a „representative way". However, there are specific requirements identified in current EU legislation. Sampling points directed at the protection of human health should be sited:

(i) to provide data on the areas within zones and agglomerations where the highest concentrations occur to which the population is likely to be directly or indirectly exposed for a period which is significant in relation to the averaging period of the limit value(s) („Hot spots");

(ii) to provide data on levels in other areas within the zones and agglomerations which are representative of the exposure of the general population („urban background").

1.5.7 Input for assessment of representativeness

The assessment of representativeness can be based on various sources of information including (a) additional measurements, (b) modelling and/or (c) the use of spatially available surrogate data. Appropriate surrogate data are parameters influencing AQ, like emissions and dispersion situation. The classification of these parameters which are spatially available enables an extension of information on AQ from the locations of AQ monitoring stations to the whole territory.

1.6 Classification and representativeness criteria

Classification schemes and methods for representativeness assessment can be based upon

1. Air quality data (measured or modelled) and their statistical analysis
2. Parameters influencing air quality, which can be subdivided into (a) emissions, (b) other anthropogenic factors related to local dispersion (building structure, land use) and (c) natural factors (meteorology, topography).
3. Receptors (human population, ecosystems, …).

These criteria are discussed in detail in chapter 2.1 and 2.2.

1.7 Statistics of air quality monitoring data

One of the main purposes of the classification of AQ monitoring stations is to support the assessment of air quality based on monitoring data. This is done by grouping monitoring stations into classes with similar „characteristics".

There are different ways of performing the classification of monitoring sites. It can be based on *a priori* available information on the location of the site and its surroundings (e.g. vicinity to emission sources, land-use, ...); such information partly reflects parameters influencing the level and temporal characteristics of air pollution, especially emissions.

In addition, statistical analyses of monitoring data itself – on specified time scales – can be used for classification.

This requires

1. the development of a definition of such „**characteristics”** of the measured data **as statistical parameters**
2. the development of a definition of a **mathematical criterion** for „**similarity**”
3. the definition of a **numeric threshold** for this mathematical criterion for grouping stations into one class or **separating** them into different classes.

The first step of the assessment of representativeness is to define **characteristics of the concentration field** which have to be assessed; in practice, this means to define characteristics of the measured concentrations.

In any case, pollutant concentrations have to be considered in the context of a certain **averaging period**; this might be e.g. 1 hour, 1 day or 1 year. The appropriate averaging period(s) may be chosen with respect to the limit/target/alert values laid down in EC legislation or WHO guidelines. For a specific pollutant, concentrations on different averaging periods therefore have to be taken into account.

On the other hand, the characteristics of pollutant concentration may change over time due to e.g. changes in emissions or building structure. Therefore the classification of monitoring stations may change over time, and it might be misleading to use long time series for the classification and the assessment of representativeness of a monitoring station.

Nevertheless, the temporal variation of pollutant concentrations (e.g. hourly, daily averages) over a specified period (e.g. 1 year) has to be taken into account for the classification of a monitoring station and the assessment of its representativeness.

Possible **parameters to characterise** the **pollutant concentrations** are listed in Table 2. These parameters have to be selected in any case with respect to a specified time period.

Table 2: Parameters to characterise the (measured) pollutant concentration field.

Parameter	Literature reference
Whole time series (hourly, daily values) over a specified time period	Chan&Hwang WMO GAW (1994) Geymayer (1992) Kim et al (2005) Lebret et al (2000) Loibl (1992) Snel (2004) Spangl (1993) van der Wal (2000) Wilson et al. (2005)
Mean or maximum value	EEA (1998) Blanchard et al. (1999)
Maximum values (daily, monthly, annual)	Blanchard et al. (1999) EEA (1998) Spangl (1993) Umweltbundesamt (1998)
Percentiles	Flemming et al. (2005)
Daily or weekly variation	Flemming et al (2005)
Statistical frequency distribution	Enke et al. (1998)

A selection of **statistical/mathematical parameters to assess the similarity** of measured air quality data is given in Table 3.

Table 3: Statistical parameters to assess the „similarity" of air quality data.

Parameter	Reference literature
Numeric difference or ratio	EEA (1999) Blanchard et al. (1999)
Correlation	Spangl (1993) Umweltbundesamt (1998)
Coefficient of divergence	Wilson et al. (2005) Kim et al. (2005)
Reliability coefficient	Lebret (2000)
Mean quadratic difference	---
Cluster analysis	Snel (2004) Flemming et al. (2005) Loibl (1992)
Principal component analysis	van der Wal et al. (2000)
Concentration ratio (e.g. NO/NO_x)	Snel (2004)
Variogram („structure function")	Geymayer (1992)
Meteorological parameters	GAW-DACH: Fricke et al. (2000)

2 DEFINITION OF THE CLASSIFICATION OF MONITORING STATIONS

2.1 Discussion of possible classification schemes

As stated above, the classification of monitoring stations serves the purpose of interpretation of AQ monitoring data. Classification is the grouping of monitoring stations (or in more general terms, geographical locations) according to certain properties of the station which are relevant for the interpretation of the measured data. Several different properties can be selected; the selection should therefore depend on the purpose of the user.

Classification schemes can vary according to the degree of complexity. There are a number of pros and cons for preferring simple over complex systems (some are listed in Table 4), again depending on the purpose.

Table 4: Simple and complex classification systems.

	Advantage	**Disadvantage**
Few, simple criteria	Allows simple comparisons on a European scale Low probability of misclassification	Insufficient separation of different types of sites
Many criteria	Detailed information about different types of sites Clear separation of sites with different characteristics	Too many classes do not support comparisons on a European scale Higher probability of misclassification or incomplete classification Would possibly ask too much from users

Obviously, a classification based on a larger number of criteria will require additional effort from network managers to find the necessary data. However, this effort is quite small compared to the resources needed for running a network, while the usefulness of the network will be considerably enhanced. Classification criteria are external parameters providing relevant information on the location of a monitoring site. In principle, each location should be classifiable – at least those locations which fulfil the siting criteria of the Air Quality Directives (AQD).

The classification of AQ monitoring stations is an important prerequisite for the assessment and interpretation of AQ data. Classifications of AQ monitoring stations are useful for various applications:

1. AQ assessment requires the grouping of monitoring stations into classes which can be characterised by external parameters – the present methodology uses the same parameters which influence AQ.
2. Investigation of the sources of air pollution and information about other **parameters influencing AQ**. Grouping monitoring stations into **classes** influenced by the same parameters is of interest for the development of abatement measures.
3. Information about receptors present in the vicinity of the monitoring station can be used as a first approximation for exposure assessment.
4. Classification can be the basis for an assessment of representativeness.

Potential criteria for classification are those influencing air pollution concentration levels. Some of these factors are pollutant-specific.

Factors influencing air pollution levels include:

- Population distribution/settlement structure (which is a more or less appropriate indicator for emissions, especially from domestic heating);
- (Potential) influence by emission source categories (here, differentiation on different spatial scales is also possible);
- Dispersion situation (including atmospheric chemistry);
- Regional background concentrations.

Data on these factors should be available as meta-information for every station.

Which of these also need to be included in the classification scheme (which should rely on a subset of the relevant meta-information) depends on the potential use of the classification scheme.

In this study, we are using a rather inclusive approach (including a list of possible classification criteria), but wish to point out that – depending on the user requirements – this list could be condensed to a number of (pollutant independent) core parameters.

2.2 External parameters influencing AQ

Parameters determining pollution levels include

1. **Emissions** – on various spatial scales
2. **Dispersion** – triggered by meteorological parameters, which might in turn be influenced by topographic features
3. **Atmospheric chemistry** – triggered *inter alia* by meteorological parameters
4. Depletion/removal – triggered by meteorological parameters, surface characteristics and emissions (ozone titration by nitrogen oxide, NO).
5. Large-scale background concentration.

It is important to note that these parameters may act at different spatial scales.

Emissions are the most common influencing parameter to be assessed. Emissions are a key parameter for common station classification systems; in most cases, the vicinity to a predominant emission source category is used for classification of the monitoring station. The major point of interest for classification according to emissions is information about the sources of pollution which have to be taken into account e.g. for reduction measures.

A more detailed classification according to emissions requires knowledge about the **contribution** of various **emission sources**. To quantify this information exactly would require the application of models. In most practical cases, classification according to emissions is based upon **expert judgement**.

A thorough classification according to emissions requires the definition of clear criteria for the different classes. This can be rather simple criteria (e.g. distance to emission sources) or more sophisticated criteria (e.g. contribution of different sources to pollution levels in per cent). This would usually require the use of models.

Besides emissions, a variety of **atmospheric parameters** determine pollution levels:

- **Dispersion situation** due to **meteorological** parameters: Wind speed, atmospheric stability, height of mixing layer, … Such parameters are largely dependent on climatic conditions (oceanic, continental, Mediterranean) and the topographic location.

- **Dispersion situation** due to **topographic** features: Width of the valley, location in basin, location in flat terrain, but also local features like building structure or land use.
- **Atmospheric chemistry**: Photochemical activity due to the amount of solar radiation and temperature, liquid phase chemistry depending on humidity, …
- Depletion by dry **deposition** (depending on surface characteristics) or wet deposition (depending on humidity and precipitation).

Classification schemes according to these parameters identify locations in different terrains with different dispersion situation, to classify areas with different ozone formation potentials or with different amounts of depletion by deposition.

The above mentioned parameters influencing pollution levels are divided into **natural** and **anthropogenic** factors and listed in Table 5.

Classification according to parameters influencing air quality may yield information on which parameters – usually emissions – can be changed by measures to control air pollution, and which are external (natural) factors that have to be taken into account and cannot be altered.

Table 5: Emissions, meteorological and topographic parameters influencing pollution levels.

	Natural	**Anthropogenic**	**Importance at a local scale**
Emissions	Natural dust, volcanic SO_2 (of minor interest in most parts of Europe), …	Anthropogenic emissions	+++
Dispersion	Meteorological/climatological conditions, topography	Building structure and heat islands – only important in urban environments	+[2]
Atmospheric chemistry	Meteorological/climatological conditions	concentration of pollutants which influence the chemical process	-
Depletion	Meteorological/climatological conditions, vegetation	Land use, emissions	+[3]

2.2.1 Emissions

A classification scheme for practical use according to emissions has to

- be specific to a pollutant;
- determine which contribution to the total concentration measured represents the „major” or „predominant” source which is used for the classification, and if only one or more sources or source categories shall be used for classification;
- determine if emissions are attributed to source categories (e.g. SNAP) or to a certain emission source (e.g. a certain street or industrial plant);
- determine if sources at different distances are treated separately (e.g. different streets or only „traffic”);
- determine if long-range transport or large-scale background concentrations are considered a „source” or are attributed to relevant sources themselves.

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[2] The building structure might exert a major influence on kerbside AQ.

[3] NO emissions might exert a major influence on kerbside ozone levels.

Table 6: Literature references for classification schemes according to emissions.

EUROAIRNET (EEA, 1999)
EoI (1997)
AirBase (DEM) (MOL 2005)
FLEMMING ET AL. (2005) partly

Common classification schemes of AQ monitoring stations according to emissions consider traffic and industrial emissions; emissions from domestic heating are usually characterised by an urban environment or the population number or density (EoI, EEA). In most cases, classifications of traffic stations are not based on emission data but on surrogate data like traffic volume and road width.

An exact classification of AQ monitoring stations according to emissions requires the knowledge of the contributions of various sources to the measured concentration. It is, if course, specific to each pollutant.

An investigation of those emission sources which determine the measured concentration requires

1. identification of relevant sources,
2. assessment of the relative contributions from these sources.

The exact contributions of different emission sources to the measured concentration can only be assessed by air quality modelling or source apportionment methods.

Otherwise, thorough expert judgement is necessary for estimating the contributions of different sources.

Besides the emissions themselves, also

1. the distance of relevant sources on various spatial scales,
2. long-range transport (which is, in many cases, not easily attributable to specific sources),
3. atmospheric processes

are relevant parameters.

The pollutants taken into account are NO_2, PM10 and ozone. The „emissions" of these pollutants show the characteristics and differences listed in Table 7.

Table 7: Characteristics of (anthropogenic) emissions of NO_2, PM10 and Ozone.

	Sources	**Spatial features**
NO_2	>50% NO_x from (road) traffic.	Local emissions dominate with respect to short atmospheric life time (< 1 day)
PM10	Many source sectors (traffic, domestic heating, industry) with varying contributions in different regions; large portion of secondary particles	Contributions from large areas due to long atmospheric life time (several days)
Ozone	Secondary pollutant from various sources of precursors	Spatial allocation of sources of precursors is difficult; large contribution from continental background

2.2.1.1 Road Traffic

Road traffic is the dominating source of NO_x (NO_2) and a major source of (primary and secondary) PM10. Emissions from road traffic are characterised by a very high spatial variability: they are confined to roads, which have highly varying emissions themselves, depending mainly on traffic volume, the proportion of diesel cars and HDVs, traffic situation (e.g. congestions).

2.2.1.2 Domestic heating

Emissions from domestic heating and their spatial distribution depend, *inter alia*, on the types of heating systems used (coal, wood, oil, gas, district heating, electricity, …) with largely varying emission factors for NO_x and PM10. Nevertheless, emissions from domestic heating usually have a more uniform spatial distribution compared to traffic and industrial emissions.

2.2.1.3 Industrial and commercial emissions

The description of industrial and commercial emissions and their contribution to measured air quality poses the problem of quantifying emissions from specific sources and of quantifying their relative contribution to measured air pollution. In many cases, only emissions from large sources are well known; on the other hand, emissions from small commercial units are not at all known, especially fugitive PM emissions.

2.2.1.4 Agriculture

Emissions from agriculture – mainly PM10 – originate a) from exhaust of off-road machinery and b) from suspension of soil or biogenic material caused by agricultural activity. The quantification of off-road exhaust emissions is mostly feasible from activity data, whereas the assessment of diffuse (re)suspension emissions is extremely difficult, as well as its spatial and temporal allocation.

2.2.1.5 Natural sources

Natural sources are of relevance mainly for PM10, but in high mountains also for ozone (stratospheric intrusions), see Table 8. On request of the European Commission, the JRC in Ispra is currently developing a guidance document on how to take into account natural sources in air quality assessment. On 12th and 13th October 2006, a workshop was held to discuss methods for attributing natural contribution to PM (see **http://natsources.jrc.it/**).

Table 8: Natural sources of ozone and primary PM10.

Long-range transport of dust from the Sahara	Contributes on average above 50 µg/m³ on one day per year to daily mean values in central Europe. Contributions to PM10 concentrations in southern Europe may be much higher.
Wind erosion from (naturally) barren areas in Europe	The assessment of natural soil erosion (wind erosion) is extremely difficult; data from Austria do not indicate a noticeable contribution of such PM10 sources*.
Sea salt spray	Contributes to PM10 in coastal areas.
Volcanic dust.	Parts of Sicily
Stratospheric ozone	Contribution of a few per cent to high alpine concentrations (higher fraction at peak values)

* *see presentation of C. Nagl at the workshop „Contribution of Natural sources to PM levels in Europe" held in Ispra (**http://natsources.jrc.it/**)*

The new Air Quality Directive allows excluding natural contributions to high PM10 concentrations from limit value exceedances, thus taking into account that in some parts of Europe natural sources may contribute quite significantly to PM10 levels. However, the respective regions – southern Europe, affected by dust transport from the Sahara – are quite well known. Introducing natural sources as a classification parameter would not give much additional information, but only separate the southern Mediterranean regions from the rest of Europe. In addition, the difficulties and uncertainties encountered in determining the contribution of natural sources to PM10 concentrations justify the disregarding of natural sources when creating a basis for a classification scheme.

2.2.1.6 Sectoral and spatial distribution of emissions

Information on major emission sources is not only important for abatement measures, but also for the selection of surrogate data for the classification of monitoring stations.

For the design of measures, both the sectoral as well as the spatial distribution of emissions is necessary. The following chapter discusses the spatial distribution of emissions from different sectors.

Table 9: Spatial distribution of emissions.

Source	Characteristics
Road traffic	Networks of streets with strongly differing emissions. Minimum scale in towns 100 m.
Domestic heating	Areas with more or less homogeneous emissions. Scale of variability 1000 m
Commercial or small industrial plants	Spatial allocation difficult and incomplete in most cases; large spatial variability.
Large industrial plants	Few large sources, emissions well known
Agriculture (off road machinery, soil suspension, stable emissions)	Temporally and spatially heterogeneous emissions, very incomplete information

Emissions from traffic and domestic heating are in most cases well represented in emission inventories; their spatial distribution and relevant scale are fairly well known.

Since traffic emissions are spatially more heterogeneous than those from domestic heating, and take place at an elevation closer to monitoring stations (near ground level), the spatial distribution of traffic emissions in relation to monitoring sites is more crucial than for domestic emissions.

In small towns or rural environment, traffic, domestic and industrial emissions and their spatial distribution are of less importance; on the other hand, agricultural emissions can be more relevant.

Regarding long-range transport, it is usually not possible to identify specific sources and their contribution at a certain monitoring site without additional analysis.

2.2.1.7 Data sources

Information about the relevant emissions can be obtained from various data sources. Besides emission inventories, emission data for specific industrial sources, or based upon the traffic census for certain roads, can be used. If no emission data are available, traffic census data or population numbers and distribution can be utilised as surrogate data.

Table 10: Data sources for emissions on various spatial scales.

Emission	Data sources
Traffic	classification based solely on traffic census traffic census + emission factors emission inventory
Domestic heating	population density information on heating structure emission inventory
Commercial and industrial	number and distribution of people working in specific industries emission data for specific sources emission inventory

2.2.1.8 Long-range transport

Long-range transport contributes mainly to ozone, PM10, and SO_2. Due to their short atmospheric life-time (less than 1 day), it is of minor importance for NO_2 (NO_x).

The attribution of long-range transport to certain sources may be difficult. The attribution to source regions and a rough quantification of the contribution of long-range transport can be part of a classification scheme.

2.2.1.9 Secondary pollution

Secondary pollution due to atmospheric formation contributes to PM10 to a significant extent, and to total ozone pollution.

A contribution from secondary pollution – important for particulate matter – can either be attributed to the sources of the precursors of secondary pollution, or simply classified as ”secondary pollution”.

With respect to the major difficulties and uncertainties encountered when determining the share of secondary particles and their attribution to certain sources, secondary pollution is not further considered to provide a basis for a classification scheme.

2.2.2 Atmospheric and topographic conditions determining the pollutant concentration

Besides emissions, various atmospheric factors determine the pollutant concentration:

1. dispersion situation – during the whole atmospheric life-time of a pollutant,
2. atmospheric transport – distance between source and receptor depending on the life-time of a pollutant,
3. atmospheric transformation,
4. deposition.

Many of these factors are determined by meteorological, climatological, topographic and land-use conditions, which can be utilised for the classification of a monitoring site.

The purpose of a classification of monitoring stations according to these criteria is to separate the influence of (similar) emissions from „external” (in most cases non-anthropogenic) factors which can in fact not be altered by any measures.

2.2.2.1 Dispersion situation

The dispersion situation determins the amount and speed of the dilution of pollutants emitted into the atmosphere. Dispersion is determined by meteorological and topographic parameters like

- vertical temperature gradient and its temporal variation,
- wind speed and its temporal variation,
- occurrence of high and low pressure systems,
- topographic situation – valley, basin, plain – on various spatial scales,
- building structure (can be considered as an „anthropogenic" and very small-scale topographic feature influencing local dispersion),
- periodic thermotopographic circulations (valley or slope wind, sea breeze circulations) can either lead to a dilution or to a recirculation of pollutants.

On the other hand, the topographic situation is crucial for dispersion; locations in valleys and basins are more likely to be affected by an adverse dispersion situation than locations on slopes or summits.

What is relevant for ozone is the concurrence of ozone depletion near the surface and exchange with the reservoir layer or the free troposphere; the latter process leads to comparably high long-term ozone levels at elevated mountainous locations like slopes and summits.

The following scales have to be taken into account (Table 11):

- Dispersion in the immediate vicinity is influenced by near-by buildings or trees, but also by the local topographic situation.
- Dispersion is influenced by the regional topographic situation, which can inhibit the dilution of locally emitted pollutants and influence the local wind systems and the frequency of stagnant inversion situations.
- On a larger scale, the topographic situation influences advection and exchange of air masses (oceanic – continental) as well as long-range transport.
- Dispersion is influenced by the climate – higher wind speed and more favourable dispersion situations in oceanic climates contrast with adverse dispersion situations in cold continental air masses.

Table 11: Classification of parameters influencing dispersion and formation

Local situation (<100 m)	building structure (street canyon, detached buildings, free air flow) vegetation (dispersion, depletion) local topography (valley, plain, slope, summit)
Regional dispersion (up to 10 km)	Topographic situation: Plain, basin, valley, highlands, mountains
Measo-scale transport (100 km)	Shading from advection of oceanic air masses; regional pollutant accumulation
Climatic conditions (influencing atmospheric chemistry and large-scale dispersion situation)	Oceanic, Transitional; Continental, Mediterranean, Arctic

2.2.2.2 Atmospheric chemistry

Atmospheric chemistry can lead to both formation and depletion of pollutants on various spatial and temporal scales, as given in Table 12.

Table 12: Atmospheric life time and transport distances of pollutants.

Pollutant	Atmospheric process	Temporal Scale	Spatial Scale
NO_2	formation from NO	some minutes to hours	some m to 100 m
NO_2	chemical reactions including oxidation to nitric acid	several hours	some km to 100 km
Ozone	formation by complex photochemical processes	hours to days	some km to 1000 km
Sulphate, nitrate, secondary organic matter	formation from SO_2	hours to days	some km to some 100 km
SO_2	oxidation to sulphate	hours to days	some km to some 100 km

Atmospheric chemistry depends on various meteorological parameters like

- temperature,
- solar radiation,
- humidity,

but also on the amount of local and regional pollutant dispersion.

2.2.2.3 Depletion

Depletion (removal) of pollutants can occur by chemical reactions, dry or wet deposition.

Dry deposition is pollutant dependant and is mainly influenced by deposition velocity which is determined by the surface, i.e. by land use. Wet deposition is determined by cloud formation, rain and snowfall.

2.2.2.4 Spatial scales

The spatial scale of influence also has to be taken into account:

- local dispersion situation, triggered by building structure (street geometry), vegetation (trees) or local topography, are relevant in relation to local sources (traffic, domestic, industrial);
- dispersion situation on the scale of a valley or basin – some kilometres up to some 10 km – are triggered by the topographic situation, but also by the climatic situation;
- dispersion situation on a scale of some 10 to some 100 km are relevant for long-range transport and are mainly determined by the climatic conditions;
- atmospheric chemistry has to be considered on a scale of some 10 to some 100 km, depending on the temporal scale of the chemical processes;
- dry deposition – relevant for reactive gases like ozone – has to be considered in connection with land-use features which trigger deposition velocity.

Literature references:

EoI requires information about street geometry
GAW-DACH (FRICKE ET AL., 2000)
Meteorological applications

The classification scheme proposed in chapter 2.5 is based solely on emissions for primary pollutants incl. PM10 (the inclusion of the regional PM10 background concentration is being discussed). The dispersion situation described above is not taken into account, the rationale being that a classification scheme considering such a large number of parameters seems to be too complicated and difficult to handle because it would have to comprise a high number of classes.

However, the atmospheric and topographic conditions described above will provide a key input for an assessment of representativeness.

2.3 Receptors

Receptors of interest are:

1. Human population
2. Vegetation/ecosystems: forests, crops

For a classification of monitoring stations based upon these receptors, the presence of receptors – and, if this information is available, the number, area covered or distribution – in the vicinity of the monitoring station is used. The distance for „vicinity" has to be defined.

2.3.1 Population distribution

The information about receptors present in the vicinity of a monitoring station – human population, ecosystems and vegetation (forest, crops) – is relevant as a basis for exposure assessment. Although, for exposure assessment, spatial information about AQ is needed, the presence of receptors in the vicinity of a monitoring station allows a first approximation about which monitoring stations are representative of which receptors. From a legal point of view, there are also differences concerning the receptors. Limit values for the protection of human health have to be attained throughout the territory of the Member States, while compliance with the limit values for the protection of vegetation and ecosystems is restricted to certain areas.

Simple classifications based upon the population distribution – related to administrative areas – are common in currently used classification schemes and meta-data sets. More refined classification methods can be based upon the population within a certain distance from the monitoring site. Such classification schemes differentiate between urban and rural locations; urban locations can be differentiated in (central) urban and suburban, rural sites in near city and remote locations.

These classification schemes can be used as simple surrogate information for the assessment of emissions, especially from domestic heating, and as a simple basis for an assessment of representativeness in terms of receptors – urban sites for human population, rural sites for vegetation or ecosystems.

A classification scheme based on population distribution can provide an input for exposure assessment.

2.3.2 Ecosystems

As a basis for a classification according to ecosystems (vegetation; forest, crops), the presence of these ecosystems in the vicinity of the monitoring station can be used. Nevertheless, the relation of a monitoring site to ecosystems in its vicinity tends to be an issue in the assessment of representativeness.

2.4 Existing description schemes of monitoring stations (meta-information)

The descriptions of AQ monitoring stations (meta-information) laid down in the reporting requirements of EC legislation have been designed as a basis for the classification of monitoring stations. The description scheme is given in the Exchange of Information (EoI) Decision 97/101/EC (modified by 2001/752/EC), and also used for reporting under the Ozone Directive 2002/3/EC.

The EoI requires information on the „type of area" (Annex II, II.2.1) and „type of station in relation to dominant emission sources" (II.2.2), see Table 13.

Table 13: Classification of stations according to the Exchange of Information Decision.

Type of area	Type of station in relation to dominant emission sources
Urban	Traffic
Suburban	Industrial
Rural	Background

For „traffic stations", some information about traffic and street geometry is required (II.2.3.3), for „industrial stations" information about the type of industry (given as SNAP category) (II.2.3.4).

Rural background stations are to be sub-classified as near-city, regional or remote (II.2.3.5).

The EoI also requires the „area of representativeness" (II.2.3.1), although there are no methods or criteria given as to how to specify this.

Information about the micro-scale location of the site and the air inlet are required as part of the Measurement Configuration (Annex II III.2).

In the „old" version of the EoI from 1997 (and implemented in AirBase), additional (qualitative) information about the surroundings of the measurement site – e.g. „residential", „commercial", „industrial" is implemented (see also MOL, 2005) – which is in fact surrogate data for emissions and which also allows combinations of land-use characteristics.

In addition, information about the main emission source (SNAP) was required. This information poses a major difficulty in that it is related to the monitoring station, and that it is not specified to which pollutant it might refer.

The meta-information required by the EoI and available in AirBase can be used for station classifications and has been widely used by EEA (ETC-ACC) in various reports and statistical analyses.

Nevertheless, some shortcomings of this meta-information can be identified:

- no quantitative criteria for the type of area and type of station are given, and no harmonised procedure is applied throughout Europe. This makes the meta-information liable to be a personal estimate by the monitoring network operator.
- The meta-information is not related to different pollutants. The specification of a major emission source can, therefore, be quite ambiguous.
- According to the EoI, a monitoring site can only be „traffic", „industrial" or „background". But in fact, a monitoring site could be e.g. „traffic" for NO_x, „industrial" for SO_2 and „background" for lead[4].

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[4] The Austrian „industrial" site Arnoldstein is a hot spot for Pb, Cd and As in PM10 (and to some minor extent SO_2), but represents almost rural background concentrations for PM10, Ni in PM10 and other gaseous pollutants.

2.5 Proposed definition of the classification scheme

The classification scheme proposed in this study is based on emissions of certain source categories as the predominant „external factors influencing air quality".

Other external factors, like the dispersion situation – triggered by climate, topography, or building structure – could also be used, but proved to be too difficult to be included in a classification scheme as a first step. Nevertheless, this dispersion situation is considered a key input for an assessment of representativeness.

2.5.1 Classification according to emissions

The classification scheme proposed, developed and tested in this study is based upon **emissions** and takes into account the three most important source categories:

1. **Local road traffic**;
2. **domestic heating**;
3. **industrial** and commercial sources (including power plants and special infrastructural facilities like airports or ship emissions in major sea ports and harbours).

The basic features of the proposed classification scheme are:

- the classification can be applied (of course) only to primarily emitted pollutants; for ozone, a different classification scheme is being developed (chapter 2.5.2);
- the classification scheme is based upon the **absolute contribution of each source category** to the **absolute concentration** level observed at the monitoring station;
- the classification is to be performed for each pollutant separately, i.e. the classification scheme is pollutant-specific.

This classification scheme according to emissions is related to the „type of station" classification specified in the EoI meta-data (97/01/EC). It can be used to improve the meta-information according to the EoI.

The method for the classification is described in chapter 2.

2.5.1.1 Emission categories

The classification scheme is based upon the impact from

- local road traffic
- domestic heating
- industry, including commercial sources, ports, airports, waste incineration, and power plants.

The classification scheme regards the different spatial patterns of these emission categories.

Local road traffic is considered because road traffic emissions show a quite distinct spatial pattern. Road traffic emissions are allocated to the road network, which covers only a small area of the total European territory; they are very high at major roads, low within the secondary road network and zero off-road. Road traffic emissions therefore impose a distinct spatial pattern on the concentration field of traffic related pollutants, with very high concentrations in the immediate vicinity of major roads and a strong gradient in the surroundings of major roads up to some 100 m. Therefore the impact of local road traffic emissions on measured concentrations is of primary interest for the interpretation of the concentration pattern.

It should be noted that the total road traffic accounts for the predominant share of NO_x emissions in most areas (40 to 70% of total urban NO_x emissions in most of Europe) and therefore contributes even most of urban background concentrations. It may even account for a higher contribution of kerbside NO_2 concentrations than local road traffic NO_x emissions.

Nevertheless, it is justified excluding non-local road traffic emissions from the classification scheme, as these emissions are somehow evenly distributed over the urban territory, and their contribution to the observed concentration gives no additional information on specific sources influencing the monitoring site.

Domestic heating emissions are clearly related to human population, although – as pointed out in chapter 6 – emissions per capita may vary largely, especially for PM10. Nevertheless, domestic heating emissions show quite an even spatial distribution compared to road traffic.

As Figure 1 clearly shows for the example Klagenfurt Koschatstraße, domestic heating is not at all the predominant NO_x source even at urban background sites, but the largest contribution to NO_2 background concentrations originates from total road traffic emissions in the towns.

Industrial emissions show no regular spatial pattern at all. As pointed out in chapter 6, no easy method can be given for estimating the contribution of industrial emissions to measured concentrations.

The classification scheme does not cover **emissions** from the following **sectors**:

- road traffic not in the vicinity of the monitoring station
- off-road machinery
- agriculture
- natural PM sources

This is, partly, justified by the fact that the quantification and spatial allocation of emissions from off-road machinery, agriculture, and natural PM sources is very difficult. These sources are also less relevant in general.

Also, secondary pollutants and long-range transport cannot be covered.

2.5.1.2 Contribution of emission sectors

As an example, Figure 1 shows the estimated contributions from local road traffic, domestic heating, industry and non-local road traffic to the observed annual mean NO_2 concentrations at the three traffic related sites Klagenfurt Völkermarkterstraße (TU GRAZ 2007), Wien Hietzinger Kai and Taborstraße (UMWELTBUNDESAMT 2007) and the urban background site Klagenfurt Koschatstraße in Austria. (The contribution from domestic heating, industry (including district heating), non-local road traffic and off-road cover the urban background, which was, as a rough estimate, attributed equally to the relative share of these emission categories.)

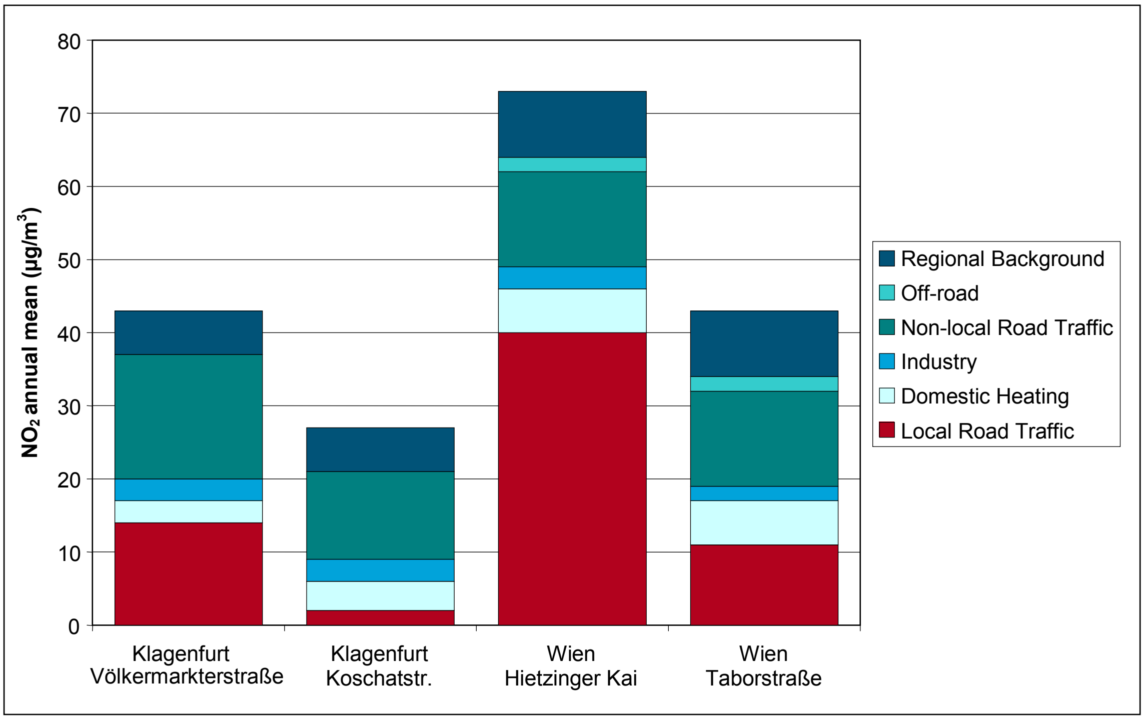

Figure 1: Contributions of major emission sectors to annual mean NO_2 concentrations (2005) at urban monitoring stations in Austria.

It should be noted that the influence of traffic emissions refers only to road traffic, since road traffic emissions show a fairly regular spatial and temporal pattern throughout Europe. Other types of traffic – rail, air, shipping – as well as off-road machinery emissions have a totally irregular spatial distribution and are considered not appropriate for a general classification scheme. These types of emissions are included in „industrial emissions".

Figure 2 shows the contribution from different PM10 source categories, as estimated for several monitoring stations in Austria: Wolfsberg (UMWELTBUNDESAMT 2005c), Imst (UMWELTBUNDESAMT 2005b), Klagenfurt Völkermarkterstraße (UMWELTBUNDESAMT 2003), and Wien Währinger Gürtel (urban background), Wien Rinnböckstraße (medium traffic), Wien Spittelauer Lände (high traffic) and Wien Liesing (industrial) (UMWELTBUNDESAMT 2004). The source contributions were estimated for winter averages rather than annual averages, since these studies which investigated the sources of PM10 limit value exceedances focused on situations with high PM10 concentrations. The PM10 measurements refer to different years between 2003 and 2005, Spittelauer Lände to 2000/01. The contributions from the different sectors are estimates and should not be regarded as exact numbers; the large uncertainties are not only due to insufficient knowledge of PM10 emissions, especially from road resuspension and diffuse industrial sources, but also to gaps in knowledge of secondary particle formation and the separation of local and regional concentrations in alpine basins and valleys (whereas estimation of the regional contribution in Wien is based on comparisons with regional background sites). The various studies do not cover all emission sectors – for example, „construction" is only considered in Imst, „off-road" only in Wien.

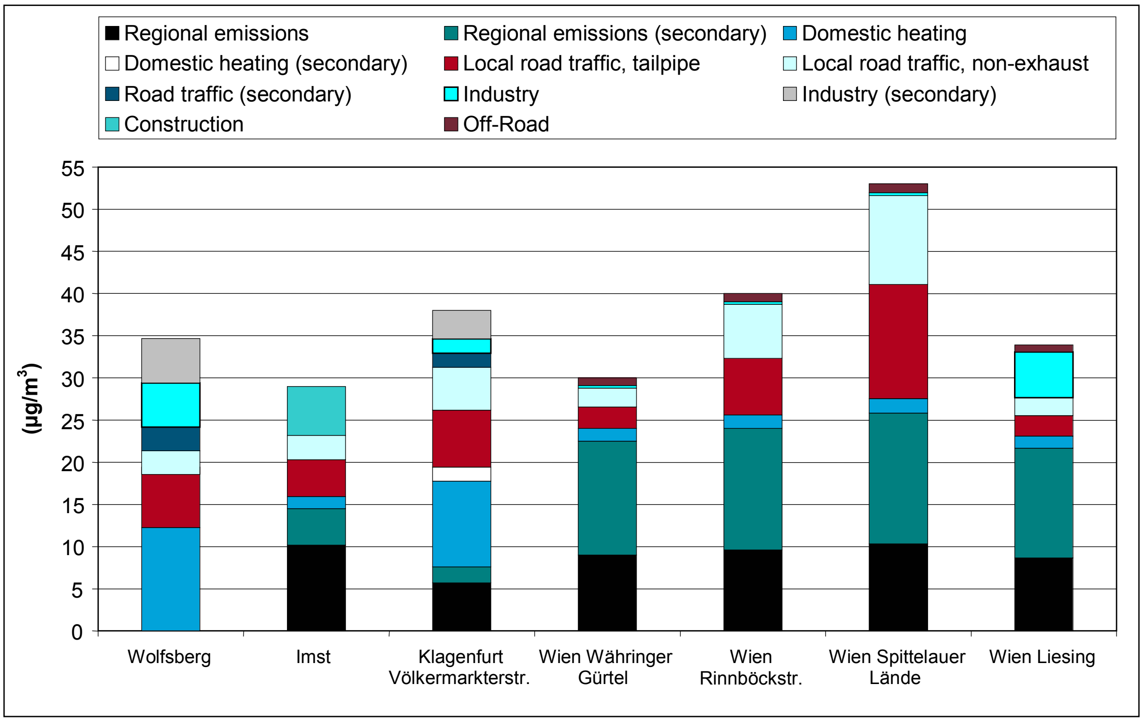

Figure 2: Contributions of major emission sectors to PM10 concentrations at different monitoring stations in Austria.

Figure 2 shows that different source categories give quite different contributions to PM10 concentrations – even with respect to the high uncertainties about these source apportionments. Especially urban stations in alpine basins (Wolfsberg, Klagenfurt) show high contributions from domestic heating, caused by a high proportion of wood burning. Local road traffic gives largely varying contributions, and non-local road traffic constitutes the major share of the „regional contribution" for Imst. At this site, construction activities were responsible for a specifically high contribution to PM10 pollution.

The classification according to **emissions of primary pollutants** (with a separate classification scheme for ozone) is limited in that secondary aerosols – as a major contribution to **PM** – are not covered.

The secondary contributions from gaseous emissions of road traffic, domestic heating and industry are not attributed to these sectors. As stated in chapter 2.2.1.9, it is not possible to attribute secondary particles to certain sources, therefore secondary pollution is not dealt with by the classification scheme as a pragmatic approach.

The classification according to emissions is related to the **absolute contribution of each emission category to the observed pollution level of a specific pollutant**. The absolute contribution has to be taken into account in order to enable comparability of all monitoring sites with quite different pollution levels – for example, the predominant relative contribution at a remote site may originate from industrial emissions, but at quite a low absolute concentration level.

The assessment of the contribution of different source categories can be carried out by using various methods, of which modelling may be the most comprehensive and accurate, but also the most expensive one. Most commonly, the assessment of the contributions of different sources is accomplished by a combination of expert judgement, the use of emission inventories and modelling.

The three emission categories used as a basis for classification do not necessarily give absolute contributions of comparable level, and are not to be compared with each other. As Figure 1 and Table 39 show, the absolute contribution of local road traffic to the annual mean NO_2 concentration is much higher even for sites classified as „medium" (in a classification scheme with three classes), compared to the estimated contribution from domestic heating for sites classified as „high".

This means that even for urban background sites with high emissions from domestic heating, the absolute contribution from local road traffic might be higher than that from domestic heating. It can be clearly observed that for sites classified as „high" both for local road traffic and domestic heating, the absolute contribution from local road traffic can by far exceed the absolute contribution from domestic heating.

2.5.2 Classification of ozone monitoring stations

Since ozone – as an entirely secondary pollutant – cannot be classified according to emissions; formation and depletion processes have to be used for classification.

The classification of ozone monitoring sites will be based upon the following parameters:

1. Local ozone depletion by NO titration is considered by the classification of **NO_x emissions by local road traffic**; two classes are proposed (the distribution of ozone monitoring stations in relation to major roads justifies merging the two higher classes (out of three) proposed for NO_x emission classification);
2. the amount of ozone depletion on the surface and vertical mixing, which lead to a distinct vertical gradient, is dealt with by a simple topographic classification based on **exposure**:
   - „plain" for low vertical exchange and high surface depletion
   - „mountain" for good vertical exchange and low surface depletion
   - „high alpine" for locations on high mountain summits characterised by a strong exchange with the free troposphere and negligible surface depletion.
3. **Regional photochemical ozone formation** in the plumes of large agglomerations can be assessed either by
   - expert judgement
   - regional NO_x and VOC emissions within a circle of approx. 50 to 100 km;
   - 2 classes are proposed.

2.5.3 Classification according to population

The classification of AQ monitoring sites according to the population distribution separates different types of urban and rural sites.

3 CLASSIFICATION METHOD

3.1 Introduction

This study recommends in Chapter 2 a classification scheme based upon **emissions** and considers the three major types of emissions: **road traffic**, **domestic heating**, and **industry** (including commercial emissions, power plants, waste incineration, mining, harbours and airports).

The classification scheme classifies the absolute **contribution** of each of these emission sectors to the **total measured concentration** independently from each other.

The classification scheme is pollutant-dependent at least for industrial emissions. Since road traffic and especially domestic heating show quite different emission factors for different pollutants, a pollutant-dependent classification is also recommended for these sectors. The major traffic related pollutants, NO_x/NO_2 and PM10/PM2,5, show different emission factors depending e.g. on the share of diesel cars, the HDV fraction and the traffic situation. For domestic heating emissions, the situation is even more complicated with regard to the major pollutants NO_x/NO_2 and PM10/PM2,5 due to differences in heating equipment and fuel use; but also SO_2 and PAH should be considered when measuring domestic emissions.

The classification scheme does not consider all emissions. It does not include

- road traffic apart from major roads,
- off-road machinery,
- agriculture,

and it does not consider long-range transport.

One option is to include the large-scale background concentration of PM10 as a classification criterion, since this is – contrary to NO_2 – a substantial contribution to urban PM10 levels in large parts of Europe. This large-scale contribution can be addressed either as regional background concentration, or medium to long range transport. As an option for further discussions, consideration of the regional PM10 background as input for classification is discussed in chapter 3.2.6.

Any classification system is based upon two steps:

1. **Classification parameters**: These quantify the contribution of each emission sector.
2. Selection of quantitative **criteria** to **separate** the classification parameters into **classes**. The selection of classification criteria can either start at a specified number of classes, or at specified class boundaries.

In a first approach, three classes for each type of emission are proposed, and class boundaries are derived from Austrian data (see chapter 6.5).

The definition of the classification parameter for local road traffic and domestic heating is based on simple model results and the observed relation between emissions and measured concentrations. Therefore the classification parameter itself can be regarded as a very simple model which parameterises the relation between concentrations and emissions. With regard to industrial emissions (and those from all other stationary sources mentioned above), no such simple mathematical relation between emissions and concentrations can be given. Therefore an assessment of the influence of industrial emissions can be carried out by the AQ data provider using appropriate means of modelling or expert estimation.

Besides emissions, the population distribution/settlement structure is also used as a classification parameter related to exposure assessment. Population distribution can be used as a surrogate for domestic heating emissions, but is proposed as a separate classification parameter.

Classification schemes based on

- dispersion situation and
- background concentrations

are not further developed or discussed. However, these external parameters are used as key input for the assessment of representativeness.

The classification scheme discussed below presents, as a first approach, three classes for each emission category, which, theoretically, give a total of 27 classes.

The class boundaries are derived from the distribution of the emission parameter for each emission category independently, based on data of Austrian AQ monitoring sites; the Dutch sites fit quite well into this distribution (see chapter 6).

However, a harmonised classification throughout Europe would require more data from more countries, in order to ensure that the class boundaries are really representative of the whole of Europe.

3.2 Emissions

3.2.1 Emissions and activities

Emissions can generally be calculated by multiplying activity data by emission factors, e.g.

- Road traffic: traffic volume and emission factor (kg per km and vehicle)
- Domestic heating: number of households and emission per stove (kg per year)
- Industry: production and emission per unit.

Using simple activity data instead of emissions as classification parameters may de discussed. The advantages of such an approach would be

a. that data are more easily to obtain, and
b. temporal trends in emission factors would be reflected in changes of the classification.

However, this approach is not recommended in this study because the core objective of the proposed classification scheme is to group monitoring stations according to parameters which directly influence pollutant concentrations – and thus emissions. The use of activity data – e.g. traffic volume or population – would forgo the spatial variability of emission factors. For example, traffic emissions do not only depend on the traffic volume, but also on other crucial parameters like

- share of heavy duty vehicles
- traffic situation (stop & go, urban, rural, motorway).

The variability of domestic heating PM10 emissions is even higher and depends on fuel use and heating equipment. Leaving out the real emissions would result in a loss of information and rather obscure the real situation at a monitoring site.

Trends (changes) in emission factors may be reflected in measured concentrations, but it should be kept in mind that the purpose of classification is not to identify a ”classification trend”, but to obtain an overall picture of the situation throughout Europe for a specific year. Therefore, uniform criteria for the whole of Europe and a precise representation of real emissions are recommended as a prerequisite for classification.

3.2.2 Relation between emission contributions and concentrations

The source apportionment for NO_2 shown in Figure 1 for four sites in Austria clearly shows that the impact of road traffic emissions by far exceeds the impact of other emission sectors – which is not surprising since road traffic contributes far more than 50 % of the national total NO_x emissions. Therefore a classification according to different emission sectors – (local) road traffic, domestic heating and industry – is likely to correspond to different absolute amounts of NO_2 concentrations from each sector for each class.

The relation between the absolute contributions from each emission sector to the annual mean concentrations (Table 39) shows that – for a classification scheme with three classes – the class „medium" for local road traffic corresponds to about 10 µg/m³ NO_2 (annual mean) and for domestic heating 3 to 4 µg/m³. For industrial emissions, concentration related class boundaries of 10 and 20 µg/m³ (annual mean, NO_2 and PM10) are proposed in chapter 3.2.5.

The classification does therefore not reflect the absolute contribution of different emission sectors; the absolute contribution of local road traffic of a station in class „high" is not comparable to the absolute contribution of a station in class „high" for domestic heating. This is a discrepancy which is accepted, because otherwise a large majority of stations would be classified as „low" according to domestic heating, and the classification would in fact only reflect different amounts of road traffic emissions, which make up the (by far) dominating emission sector for NO_x.

3.2.3 Local Road Traffic

3.2.3.1 Classification parameter

The classification parameter is the potential contribution from local road traffic to the measured concentration of NO_2, NO_x or PM10. „Local" road traffic has to be taken into account, since road traffic on a wider spatial scale also influences the measured concentrations by its contribution to the background concentration.

The contribution of local road traffic emissions to the observed concentration may be assessed by modelling or estimation using surrogate parameters.

The classification method discussed below can be applied where modelling is not available. The contribution of road traffic emissions is referred to as "traffic parameter" and quantified by the following approximation:

Traffic emission parameter = **emissions of local road traffic divided by square root of the distance**

The square root of the distance from the road as the denominator is a rough approximation for the concentration distribution along a street from model results[5]. It underestimates the real concentration distribution near the street (distance depending on dispersion and wind conditions) and overestimates it at longer distances.

The distance to be used is the distance from the kerb of the road to the air inlet. On motorways, the distance from the kerb of the first traffic lane (not the breakdown lane or hard shoulder) has to be used.

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[5] MISKAM (EICHHORN 1989), ADMS (MCHUGH 1997)

A comparison of the traffic emission parameters calculated with the distance in the denominator is given in chapter 6.5.1.

Traffic census data can be used as a surrogate for road traffic emissions. Table 14 lists possible approximations of emissions at different levels of sophistication.

Streets with high emissions invariably have to be included in the „traffic parameter” with longer distances than smaller streets.

Table 14: Approximations for road traffic emissions.

Level	Approximation of emissions
0	Total vehicle number, uniform emission factor
1	Vehicle numbers for passenger cars and HDVs, emission factors for each of them
2	Vehicle number for passenger cars and HDVs, specific emission factors for different traffic situations (motorway, stop&go, ….)
3	Complete high resolution emission inventory

Especially in urban locations monitoring sites may be located quite close to major roads, but shielded from the road by compact buildings and therefore not significantly affected by traffic emissions (or only to a minor extent). Based on model results[5], an ”**exposure coefficient**” is introduced, which is multiplied by the respective traffic emissions. The exposure coefficient is assumed to be **0** for the configuration of a monitoring site and a road with completely closed building blocks in between (which means that in such cases nearby traffic emissions do not contribute to the measured pollution) and **0.5** for buildings with small gaps or a monitoring site located in a narrow side lane. In cases where the monitoring site and the road are located in more or less open terrain, the exposure coefficient is **1**.

On the other hand, street canyon configurations aggravate the influence of local emissions. Therefore an exposure coefficient of **1.5** is proposed for monitoring sites in street canyons with compact buildings.

3.2.3.2 Proposed class boundaries

The proposed class boundaries for the parameter describing the influence of local road traffic emissions are derived from the results for Austrian AQ monitoring sites.

Table 15 lists the maximum NO_x and PM10 emissions from road traffic – calculated at level 1 and 2 – and the maximum road traffic emission parameter (emissions divided by the square root of the distance, sum over relevant roads) for the Austrian AQ monitoring sites.

Table 15: Maximum NO_x and PM10 road traffic emissions (kg/km.day) and traffic emission parameter (g/($m^{3/2}$·day)) for Austrian AQ monitoring sites, level 1 and level 2.

		Emissions	**Traffic emission parameter**
Level 1	NO_x	164[6]	58.4[7]
	PM10	13.3[8]	4.1[7]
Level 2	NO_x	174[8]	61.4[7]
	PM10	17.8[6]	3.9[9]

Based on the distribution of the traffic emission parameter for NO_x in Austria at level 2 – see chapter 6.5.4, Figure 34 – class boundaries for the delimitation of three classes at 5 and 15 g/($m^{3/2}$·day) are proposed. For PM10 (see chapter 6.5.5, Figure 36) class boundaries at 0.4 and 1.1 g/($m^{3/2}$·day) are proposed (see Table 18).

Table 16 gives an overview of the relation between the distance from the monitoring site to the kerb and the emissions per km and day, which would fit either the lower or the upper class boundaries proposed above. For example, a street at a distance of 10 m from the monitoring site with NO_x emissions of 16 g/m·day would be classified as "medium" whereas at a distance of 1 m, it would be classified as "high".

Table 16: Relation between distance and emissions exceeding the proposed upper and the lower class boundaries for local road traffic NO_x emissions.

Distance (m)	**5 g/($m^{3/2}$·day)**	**15 g/($m^{3/2}$·day)**
	Emission (g/m.day)	
1	5.0	15.0
2	7.1	21.2
5	11.2	33.5
10	15.8	47.4
20	22.4	67.1
50	35.4	106.1
100	50.0	150.0
200	70.7	212.1
500	111.8	335.4
1000	158.1	474.3
2000	223.6	670.8

A relation between the class boundaries based upon emissions and observed concentrations can only be established by a fairly accurate source apportionment, as shown in Figure 1 and Table 39 for NO_2 for four sites (in two cities) in Austria. The results given in Table 39 roughly suggest that the class boundary for local road traffic low-medium may correspond to annual average NO_2 concentrations of about 10 µg/m³, and the class boundary medium-high to about 30 µg/m³. However, these numbers are rather tentative, due to the very small number of sites.

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[6] A1 near Amstetten

[7] Vomp A12

[8] A23 in Wien

[9] Salzburg Rudolfsplatz

One should also keep in mind that the relation between emissions and concentrations may be strongly influenced by the dispersion situation (see chapter 2.2.2), which is – deliberately – not included in the classification scheme, so as to not make it too complicated.

As for PM10, there still seem to be major uncertainties with regard to the calculation of road traffic emissions, which might be the (main) reason for mismatches between estimated contributions of local road traffic and classification results, as shown in Table 43.

3.2.4 Domestic heating

3.2.4.1 Classification parameter

The contribution of domestic heating emissions to the observed concentration may be assessed by modelling or use of surrogate parameters. The classification method discussed below can be applied if modelling is not available. It considers the domestic heating **emissions within a radius of 1 km**[10].

Table 17 lists possible approximations of emissions at different levels of sophistication.

Table 17: Approximations for domestic heating emissions.

Level	Approximation of emissions
0	Population within administrative units
1	Population within 1 km derived from GIS data
2	Population within 1 km and 10 km derived from GIS data, emission factors for specific heating structure and fuel use
3	Complete high resolution emission inventory

3.2.4.2 Proposed class boundaries

The average ”emission factor” of NO_x for domestic heating in Austria is 1.6 kg per person and year and, for PM10, 0.8 kg per person and year. This gives a range from 0 to 96 t[11] of NO_x at Austrian monitoring sites for the domestic heating parameter in a level 1 approach (see chapter 6.5.2, Figure 31).

The level 2 approach (see chapter 6.5.4, Figure 35) gives a quite different picture with a maximum emission within 1 km radius of 75 t[11]. Level 2 data would suggest class boundaries at 10 and 20 t (see Table 18).

For PM10, the level 1 approach gives the same distribution as for NO_x.

With the level 2 approach, with regionally differing emission factors, the distribution is completely different anyhow (see 6.5.5, Figure 37). Higher emission factors in rural areas compared to agglomerations ”smooth out” the distribution of domestic heating emissions; maximum emissions are still measured around the monitoring site Wien Währinger Gürtel. Class boundaries are proposed at 3 and 5 t.

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[10] Modelling results for Klagenfurt: TU GRAZ (2006, 2007)

[11] Wien Währinger Gürtel

Table 18: Proposed class boundaries for NO_x and PM10 emissions from local road traffic and domestic heating.

	Local road traffic (g/($m^{3/2}\cdot$day))		**Domestic heating (t/y in 1 km radius)**	
upper boundary	NO_x	PM10	NO_x	PM10
„low”	5	0.4	9	1
„medium”	15	1.1	20	3

A relation between the class boundaries based upon emissions and observed concentrations can only be derived from a fairly accurate source apportionment, as shown in Figure 1 and Table 39 for NO_2 for four sites in Austria. The results given in Table 39 roughly suggest that the class boundary low-medium for domestic heating may correspond to annual average NO_2 concentrations of about 2 µg/m³, the class boundary medium-high to about 5 µg/m³.

Regarding PM10, there are still major uncertainties in the calculation of domestic heating emissions, which might be the (main) reason for mismatches between estimated contributions of domestic heating and classification results, as shown in Table 43.

3.2.5 Industrial emissions

The contribution of industrial (commercial) emissions can be assessed either by modelling or by expert judgement. There seems to be no appropriate way to assess the industrial contribution by surrogate information, since industrial sources cover a wide range of different configurations, in terms of e.g. spatial distribution and the number of sources (single stack vs. fugitive emissions) of a certain plant as well as the height of emissions; further external parameters include dispersion and wind conditions.

For a classification into three classes, the absolute contribution of emissions from industrial sources has to be determined.

Class boundaries of 10 and 20 µg/m³ (referring to the annual mean) both for NO_2 and PM10 are proposed for the 3-class scheme discussed in this study.

By way of example, the modelled annual mean SO_2 concentration caused by emissions from a point source near Wien (stack height 88 m, emissions 430 kg/h) is shown in Figure 3. It shows that the pollutant concentration can not be parameterised by establishing a simple relation between emissions and distance.

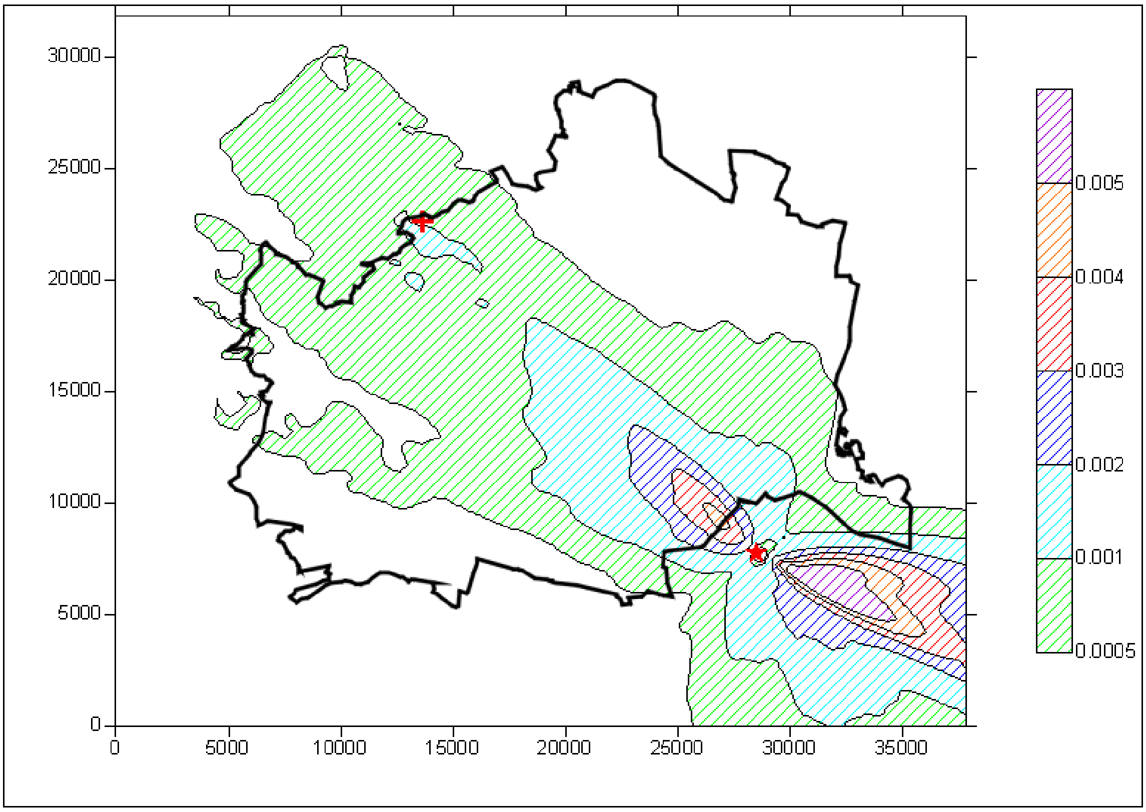

Figure 3: Modelled annual mean SO_2 concentration from a point source (mg/m³). The asterisk (in the south-east) marks the stack, the cross (in the north-west) an elevated monitoring site where a 1-hour mean value above 200 µg/m³ was measured. The units of the x-axis and y-axis are metres (UMWELTBUNDESAMT 2006).

3.2.6 Regional PM10 background

The regional background concentration can contribute significantly to urban and hot spot levels of PM10 (and also PM2.5 and PM1). Since the regional background varies largely over Europe, it can obscure the impact of urban or local emissions. For example, the regional background in the Pannonian Basin in eastern Austria contributes about two thirds of the urban background concentration in large cities, whereas in western Europe the influence of the regional background is smaller.

The regional background may be discussed as an additional classification parameter for PM10. It may be assessed by rural background monitoring (e.g. EMEP). With respect to the high levels of the regional PM10 background in central and eastern Europe, class boundaries of 10 and 20 µg/m³ (referring to the annual mean) are proposed for the 3-class-scheme discussed in this study.

3.2.7 Proposed quantification of EoI station description

The classification scheme proposed in this study may be used as a basis for harmonisation of station descriptions according to the Exchange of Information Decision (97/101/EC), with the following requirements:

- The classification is specific to each pollutant.
- Quantitative criteria are applied throughout Europe.

It is proposed that the emission parameters discussed in the chapters above should be used as quantitative criteria, and that a monitoring site is classified as a ”**traffic site”** if it falls into the classes „medium” and „high” for local road traffic emissions according to the proposed classification, and as an ”**industrial site**” if it falls into the classes „medium” and „high” according to industrial emissions.

According to this procedure, which measures the impact of traffic and industrial emissions independently of each other, monitoring stations may be described both as ”traffic” and ”industrial” stations.

For „urban background”, locations which are in the lowest class for road traffic and industry are proposed. However, especially for this class, it has to be checked if this classification corresponds to the terms used in the new air quality directive.

Rural background shall cover locations in the lowest class of all categories of emissions. The exclusion of locations with high domestic heating emissions is necessary because the medium class for domestic emissions also includes small towns which should not be referred to as rural.

3.3 Population distribution

A classification based upon the distribution of population separates urban and rural areas into areas with different population and emission densities.

The classification scheme is in principle related to the type of area description provided in the Ozone Directive (2002/3/EC) and the Exchange of Information Decision (97/101/EC). Nevertheless, an analysis of Austrian population data and the discussion of possible classification criteria to be used for the population on different spatial scales has led to a somewhat different scheme.

This scheme can be used both for exposure assessment and assessment of total emissions. Since population density is a surrogate for spatially distributed emissions, local emissions (road traffic, point sources) are not considered.

The proposed criteria are based on a combination of the population numbers within surroundings of 1 km and 10 km. A radius of 1 km refers to local emissions, whereas a radius of 10 km covers also medium-range transport and pollutant accumulation.

The population within a radius of 10 km covers the following types of area:

- Remote area
- Rural area
- Urbanised area
- Large City area

These areas are subdivided according to the population numbers within a radius of 1 km.

The definitions and class boundaries listed in Table 19 are derived from Austrian population data.

A **remote area** is characterised by a population number below 10,000 within a radius of 10 km (i.e. a population density with less than 32 inhabitants/km²). No subdivision is recommended here. E.g. in Austria, the population number is below 1000 within a radius of 1 km at all *remote* monitoring sites.

A **rural area** is characterised by a population of between 10,000 and 50,000 within a radius of 10 km (i.e. a population density with less than 160 inhabitants/km²), which is the case in large parts of the extra-alpine regions in Austria and in major alpine valleys. This type of area can be subdivided into **sparsely populated areas** with scattered farms or hamlets within surroundings of 1 km, and **small towns or villages** with compact settlements. Such small towns have a total population of up to approx. 15,000 inhabitants.

Areas with a population of between 50,000 and 200,000 within a radius of 10 km are classified as **urbanised areas**. Such types of areas cover both semi-rural regions with several small towns in close neighbourhood and dense rural habitation, as well as medium to large towns with a population of 50,000 to 150,000 inhabitants.

Areas with population numbers above 200,000 within a radius of 10 km are classified as **large city areas**. The wide range of population numbers within a radius of 1 km observed for this type of area justifies a subdivision into three categories. **Suburban** represents areas at the fringes of such large cities; **central urban areas** can be found in the central parts of cities with about 250,000 inhabitants as well as in large parts of cities with more than 1,000,000 inhabitants. The category of **densely populated central urban areas** with distinctly higher local population numbers (more than 25,000 within a distance of 1 km) can only be found in the central parts of cities with more than 1,000,000 inhabitants, but not in smaller agglomerations.

Table 19: Classification of the population distribution.

	Population within 10 km		**Population within 1 km**
Remote area	<10,000		
Rural area	10,000 – 50,000	Sparsely populated area	<1000
		Small town or village	>1000
Urbanised area	50,000 – 200,000	Small town	<8000
		Large town	>8000
Large City area	>200,000	Suburban area	<8000
		Central urban area	*8000 – 25,000*
		Densely populated central urban area	*>25,000*

The distribution of the population within a certain distance from the monitoring site shall be derived from GIS information. If this information is not available, the population distribution shall be related to administrative units.

Monitoring sites at higher altitudes with long vertical distances to larger towns, especially in alpine areas, should be classified not simply according to the population distribution. Such types of sites could be classified as „remote” even if larger towns are closer than 10 km.

3.4 Update of classification

Classification „updates" following changes of the relevant emissions (e.g. construction of a new road) and the correction of former errors – as part of the fulfilment of EC legislation - have so far not been discussed in detail. Any classification (whether EoI or the one mentioned in this study) refers to the state in a certain reference year (or period) when the assessment was performed. This reference year is usually not documented in AirBase - nor is there any information about changes of the classification.

Therefore, the following points should be discussed further:

- The necessity to re-classify monitoring stations after a certain period
- Documentation of the previous classification, once a new classification comes into force.

At present, no „history of classification" is available (at least not in AirBase), which makes it quite unnecessary to discuss how changes in the classification may affect trend analyses.

But it has to be kept in mind that classification as a requisite for data analysis can, in any case, refer only to one specific reference year. A trend analysis of a group of e.g. „traffic stations" covers stations classified as „traffic" for a certain year and cannot use information on changes of the class in earlier times – since this would not comply with the concept of trend analysis, namely that the same data set is analysed over time. The only easy way to deal with strongly changing emissions at single monitoring stations is to exclude these stations from the trend analysis.

3.5 Comparison of the proposed classification method to the status quo (EoI)

The classification method introduced in this study is proposed in order to update meta-information reported for European AQ monitoring stations under the EoI.

The basic description of the „type of station in relation to dominant emission sources" uses the classes „traffic", „industrial" and „background". The EoI text gives a short description of how these types of areas are to be identified.

The classification scheme developed in this study may be used to improve identification of traffic and industrial stations by quantitative criteria and the definition of stations which are neither traffic nor industrial stations with regard to their background (see chapter 3.2.7).

A major shortcoming of the present EoI „type of station" classification is that it refers to the „station" and does not take into account that the contributions of certain sources may differ largely for different pollutants. For example, „traffic" is relevant for NO_x and also for benzene, PM10 and CO, but in most cases irrelevant for SO_2 or heavy metals. It is also evident that industrial sources may contribute significantly to some pollutants but not to others. This classification scheme presents the data provider with the task to decide which pollutant has to be assessed for the identification of the relevant source type. A classification which is not pollutant-specific may not only confuse the data user, but also obscure the impact of some pollutants, for example a contribution to SO_2 from industry at a traffic station.

The proposed classification system is – in any case – specific to each pollutant. Therefore a monitoring site may be classified as „traffic" regarding NO_x, „industrial" regarding SO_2 and „background" regarding heavy metals.

The assessment of domestic heating emissions as discussed in the present study can be utilized to discriminate urban from rural sites.

The absolute contribution of domestic heating NO_x emissions to NO_2 concentrations is small compared especially to road traffic, but not at all negligible for PM10 and likely for B(a)P. Therefore it should be discussed if an additional source related type of area (besides traffic and industry) named e.g. „domestic heating" should be introduced in the EoI classification.

Except for some guidance notes, there are no quantitative criteria for the present „type of station" classification. The proposed classification method attempts to give such quantitative criteria, directly related to emissions for traffic and domestic heating. In this way, a better quantification and harmonisation of the classification results throughout Europe shall be achieved.

That the impact of industrial emissions is classified not by assessing emissions (due to quite different source configurations, see arguments in chapter 3.2.5), but by absolute contributions to observed levels (which have to be either calculated or estimated by expert judgement) might be considered a shortcoming.

That the absolute concentration contributions of the different emission sectors considered may be of quite different magnitudes also has to be kept in mind – and can be considered a shortcoming; due to the fact that traffic is the by far predominant NO_x source, the absolute contribution from (local) road traffic usually by far exceeds the absolute contribution from other sources. A revision of the class boundaries for different emission sectors may be discussed in order to better harmonise the classification with respect to absolute concentrations.

In any case, the relation between emissions and concentrations is strongly influenced by dispersion conditions (meteorological, topopgraphic, buildings) which themselves show a large spatial variability. Therefore a classification scheme that relates emissions to concentrations linearly will not be achievable.

Usually „background" stations are utilised for exposure assessment. This does not change by applying a new classification method, since the new method shall be used to identify background stations by excluding sites with high traffic and industrial impacts.

Any classification is roughly related to air quality management, since in many cases high pollution levels (limit value exceedances) are more likely at traffic and industrial sites than at background sites. The relation to air quality management will be clearer when adopting a classification scheme which is specific to each pollutant, and thus addresses more precisely locations where a certain emission source influences the concentration of a particular pollutant.

From a practical point of view, the utilisation of a new classification method requires additional efforts to gather, analyse and manage additional data. An application of the proposed classification method would require quite detailed information about

- emissions from road traffic and domestic heating
- the location/distance of monitoring stations in relation to major roads
- the contribution of industrial sources.

This information is not necessarily easily available. Nevertheless, there should be a need for such information for the purpose of air quality management, and using it for improving station classification may be an incentive to elaborate the respective data sets.

In general, it is important to note that any change of the present system and any introduction of a new system requires additional effort and has to be coordinated with all stakeholders (network operators, national and European agencies etc The present discussion of changes to the air quality reporting system provides a good opportunity to approach such changes.

4 DEFINITIONS OF REPRESENTATIVENESS

As stated in section 1.1, the representative area is an area in which air quality has „similar characteristics” compared to the location of the monitoring station[12]. In the following, a practicable definition of these „similar characteristics” is developed.

It is worth noting that the *definition* of representativeness should not be confused with the *method* to estimate whether a station is representative of another location; the method is discussed in a subsequent chapter.

The definition can be a very detailed specification of concentration characteristics.

The method specifies how to estimate for which locations/area a station is representative, based on information other than detailed concentration data; the method can only be tested/validated at locations where detailed concentration data are available and hence the definition is applied in the method testing/validation.

4.1 Introduction

Similarity of air quality may be related to absolute levels or may be quantified using statistical parameters. These statistical parameters (e.g. difference between averages or percentiles; correlation coefficient; mean square difference etc.) express how well concentration time series measured at the monitoring site of interest compare with (not necessarily known) concentration time series at another location. The monitoring site is said to be representative of the other location if the difference reflected in the statistical parameter is small enough.

The statistical parameter to be selected depends on the purpose of the assessment. E.g. for real time information of the public on exceedance of a threshold, one needs to know the area of which a measured exceedance at a *specific* hour is representative. For long term measures related to EU limit values or target values, however, the representativeness should relate to the *statistics* of exceedances: of which area is the measured **number of exceedances** in a year or the **annual mean** representative, irrespective of the specific hours on which this occurred[13].

There is a fairly large set of possible parameters – annual mean, percentiles for various averaging times, total time series of various averaging times, depending on the limit values set for a specific pollutant –, with at least in principle different areas of representativeness, and the question arises whether representativeness should be distinguished for each of these. If possible, a more practicable approach would be to use a (statistical) parameter that can, for judging representativeness, be used as a proxy for other relevant parameters.

Hence, we distinguish two groups of parameters:

1. Parameters for which representativeness is directly relevant. In view of the purpose of the current study, the statistical parameters of the EU air quality standards are the most relevant ones. Below we will discuss in particular the annual average and percentiles of concentrations.

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[12] It should be noted that representativeness can also be applied to a network of stations. In that case, it refers to the extent to which the distribution of concentrations over the stations is representative of the concentration distribution in the territory to be covered by the network. This statistical approach will not be elaborated here.

[13] An example of this is a traffic station at one side of a busy motorway, which will clearly be not representative of the opposite side when individual hours are compared, but the annual statistics of hourly concentrations may be very similar.

2. Parameters that are not directly relevant, but for which representativeness may be a proxy for other relevant parameters. In this group we will consider several statistics for the differences of the hourly or daily concentration time series.

For the first group the representativeness can be directly based on the difference of the statistical parameters in question. For the second group, more indirect parameters can be used, such as statistics of the time series of differences.

As a principle followed in this study, the area of representativeness is time-invariant over at least several years. The inter-annual variation of meteorological conditions and their spatial variability, which influence the temporal as well as the spatial pattern of concentrations, have to be taken into account. Therefore, the similarity of statistical parameters has to be ensured for a period of several years.

Representativeness may change in the long-term due to changes in emissions (and, in some cases, to changes in the local building structure) and has, therefore, to be re-assessed after a certain period.

4.2 Proposed definition

We will use the following general definition of representativeness based on two criteria:

1. A monitoring station is representative of a location if the *characteristic of the differences between concentrations* over a specified time period at the station and at the location is less than a certain threshold value.
2. The differences between characteristics are less than a threshold due to common reasons.

As characteristics of differences between concentrations, the following parameters – related to EU air quality standards – are applied:

- annual mean values;
- annual percentiles related to a certain number of exceedances allowed per year.

In order to avoid „similarity by chance” observed in one year, but not in another – due to e.g. inter-annual variations of meteorological conditions – the criterion of similarity has to be fulfilled over a few years; it is proposed that it has to be fulfilled over three consecutive years.

The second criterion – „similarity for common reasons” – is included in the definition, because similar annual mean values or percentiles can be observed by chance at different locations due to a **combination of quite different external factors**:

- Emissions from different types of sources.
- Climatic and topographic dispersion situation (including local building structure).
- A maximum extension of the area of representativeness, related to transport and chemical transformation in the atmosphere.

It is considered an essential part of the definition that a monitoring site is representative of other locations with similar concentrations only in the case that these concentrations are determined by similar emissions and dispersion situation (due to meteorological and topographic features) and is limited to an area related to the transport distance of air masses within a certain time period (see chapter 5.4).

It is obvious that in the case that only the similarity of concentrations (averages or percentiles) is considered, quite different types of locations even at very large distances might be representative of each other. The similarity of concentrations can result by chance from a combination of different emissions, dispersion situation, large-scale background, and atmospheric formation and transport over various scales. For example, a kerbside location in a region with adverse dispersion situation may have the same PM10 levels as a suburban background site in a region with high regional background levels.

The regional background concentration has been considered as a criterion for determining the representative area, but a maximum distance related to atmospheric transport and transformation has been found to be the better parameter. The usefulness and the disadvantages of the regional background are discussed in chapter 5.5.

4.2.1 Further specifications

The definition of representativeness follows the additional specifications:

- Representativeness is specific to each pollutant.
- Representativeness is constant over time, i.e. it does not include temporal variations due to random or diurnal, weekly or annual variations of meteorological conditions or emissions.
- Representativeness is therefore clearly related to annual averages or annual percentiles, and not to short-term values (e.g. related to information or alert values, which are specified as 1 hour mean values).

4.2.2 Concentration Parameters

The average over a certain time interval is one of the simplest statistical parameters to describe pollutant concentrations. **Annual averages** are used for limit values of PM10, NO_2 and NO_x, among others. A general definition of the representative area based on averages can be formulated as follows:

A monitoring station is representative of a location if the *difference between the values of the annual average concentration* at the station and at the location is less than a certain threshold value over a specified number of years.

The choice of the threshold value is pollutant-specific as well and has to consider measurement uncertainties, spatial variation of concentrations, absolute pollutant concentration, and other factors. A recommendation for averaging periods and concentration ranges is given in section 4.3.

The short-term limit value for PM10 can be formulated as follows: the 90.4 percentile of the average daily concentrations must not exceed 50 µg/m^3. Therefore, the 90.4 percentile of the daily average concentrations is a statistical parameter of interest. For ozone, the target value of 120 µg/m^3 (highest 8-hour mean of each day) may be exceeded 25 times per year. Therefore, the number of interest is the 93.2 percentile of the highest 8-hour average of each day.

For PM10, a monitoring station is representative of a location if the *difference between the values of the 90.4 annual percentile of the daily average concentrations* at the station and at the location is less than a certain threshold value.

For ozone, a monitoring station is representative of a location if the *difference between the values of the 93.2 annual percentile of the daily maximum 8-hour average concentrations* at the station and at the location is less than a certain threshold value.

4.2.3 Reasons for similar concentrations

„Common” reasons for similar concentrations are a necessary element of the definition of representativeness. The reasons for (causes of) the observed concentration level (and its temporal variation) can be classified as:

- emissions;
- atmospheric processes: dispersion situation – for which buildings and the topographic situation may be crucial –, atmospheric formation; transport; depletion;

It should be noted that the dispersion situation does not refer to meteorological conditions, which may vary on a short time scale, but to dispersion due to buildings, topography and climate, which is constant over time.

The impact of these factors and associated atmospheric processes, which determine dispersion, formation and depletion, can only be assessed in detail by modelling. Modelling would be the optimum method for determining representativeness; however, the methodology presented in this study covers also applications where modelling is not available but GIS information instead such as emission inventories, land-use and population density. This information is linked both to concentrations and the dispersion situation by semi-empirical relations.

The regional background concentration – resulting from medium- to long-range transport and atmospheric formation (ozone, PM10) may also be used as an external parameter. The regional background concentration refers to a scale of some 50 to 100 km. Atmospheric processes on a smaller scale can be assessed more easily by expert judgement on the basis of GIS information.

Therefore, the external parameters proposed for determination of representativeness are:

- emissions from different types of sectors – related to the classification proposed in chapter 3.2;
- the dispersion situation on different spatial scales;
- regional background concentration[14];
- atmospheric transformation processes, whose approximate spatial scale determines a maximum extension of the representative area.

4.3 Recommendation for an operational definition

4.3.1 Statistical parameters and period

For the purpose of this study, **definitions based on averages and percentiles** are proposed, namely those averages and percentiles which are compatible with the parameters used in air quality legislation:

- Annual average (PM10, PM2.5, NO_2, NO_x);
- 90.4 annual percentile of the daily average (PM10) for one year;
- 93.2 annual percentile of the highest 8-hour average of each day (ozone) for one year;

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[14] See discussion in chapter 5.5 about the regional background concentration not being used in the proposed operational method.

Deliberately, we did not include the one-hour average limit value for NO_2, since it is more difficult to assess the representativeness of short-term mean values, whose exceedances represent a very high percentile. At most stations in Europe, 200 µg/m³ as 1-hour mean value is not exceeded and there is no clear statistical relation between the number of exceedances and the 99.8-percentile of the NO_2 one-hour mean values. In addition, this value is, from a regulatory point of view, less relevant since the annual limit value is in general the more stringent limit value.

In order to take into account the inter-annual variability of the meteorological conditions especially, which may lead by chance to similar concentrations in one year, but not in another, the criterion of the similarity of the annual means and percentiles has to be fulfilled in at least three consecutive years.

4.3.2 Discussion of threshold values

As the second important part of the definition, threshold values have to be defined, i.e. the boundary between what is „representative" and „non-representative".

To define such a threshold, the following points have to be taken into account:

- Typical spatial variations of concentrations throughout Europe
- Measurement uncertainty of the pollutant[15]
- How sensitive is the representative area to changes in the threshold value?
- What is in practice realistic, for which threshold do we find reasonable coverage of the territory with a reasonable number of monitoring stations?

The threshold should be higher than the total measurement error. On the other hand, it has to be small enough to allow a clear distinction between areas with different pollution levels.

Note: In two studies (BLANCHARD ET AL. 1999; CHOW ET AL. 2006, see also chapter 2.2 of the Interim Progress Report) the threshold values were set at 20% of the concentration measured at the monitoring station. This value, which was proposed for short-term measurement campaigns, is rather high when dealing with annual averages. If a threshold value of 20% of the limit value (i.e. 8 µg/m³ for the annual mean of 40 µg/m³) were applied to annual averages of PM10 data from typical European monitoring stations, very large representative areas would be the result. For example, applying a range of ± 8 µg/m³ to the Austrian monitoring station of Eisenstadt (small town; annual average of 35 µg/m³ in 2003) would make this station representative of all other Austrian PM10 monitoring sites (about 90) except the four with the lowest and the four with the highest pollution levels.

On the other hand, the threshold value has to be higher than the measurement uncertainties of annual averages and percentiles respectively (which are of course smaller than the measurement uncertainties of short-term averages).

The numeric threshold value should be related to the range of annual mean concentrations, (or percentiles, exceedance numbers) actually measured. This is of relevance especially for ozone, for which the 93.2 percentile in Europe is between about 100 and 150 µg/m³, i.e. between about 80 and 125% of the equivalent of the target value. This can be attributed to the high continental background concentration.

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[15] In the AQ monitoring network of the Austrian Federal Environment Agency, the total uncertainty of measurements for SO_2, NO_x, CO and ozone ranges between 5 and 10%.

For NO_2, the observed annual mean values cover the whole range from almost 0 for remote rural sites to more than 60 µg/m³; for PM10, the minimum annual mean is below 10 µg/m³, the maximum 89 µg/m³[16]; the minimum 90.4 percentile is below 20 µg/m³, the maximum 160 µg/m³.

4.3.3 Recommended threshold values

We propose setting the threshold values for averages and percentiles at **10% of the total range of values observed in Europe**. This means that the total observed concentration range is separated into 10 classes.

Based on the whole European data set (AirBase) of NO_2, PM10 and ozone for the years 2002 to 2004 – excluding some extremely high PM10 values in Macedonia – the concentration range observed in Europe (i.e. EU27) will give the concentration boundaries listed in Table 20.

The NO_2 annual mean concentrations in Europe (i.e. in AirBase) in the years 2002 to 2004 cover a range from 0 to about 110 µg/m³; PM10 annual mean values range between about 4 and about 90 µg/m³, PM10 daily mean 90.4 percentiles between 7 and 160 µg/m³ and the 93.2 percentiles of the daily 8-hour maximum ozone concentrations between about 40 and 200 µg/m³ (this clearly indicates that minimum ozone concentrations –contrary to the other pollutants – are far above zero).

Table 20: Recommended concentration range for „representativeness".

Pollutant	Concentration range	Concentration boundaries for representativeness
NO_2	10 µg/m³	Annual mean value at the monitoring station ± 5 µg/m³
PM10	10 µg/m³	Annual mean value at the monitoring station ± 5 µg/m
PM10	16 µg/m³	Annual 90.4 percentile of daily mean values at the monitoring station ± 8 µg/m³
Ozone	18 µg/m³	Annual 93.2 percentile of daily maximum 8-hour mean values at the monitoring station ± 9 µg/m³

For NO_x (which covers a concentration range up to more than 300 µg/m³), a value of 10% of the total concentration range observed in Europe is not useful. NO_x is of relevance only at monitoring sites where the limit value for the protection of vegetation and ecosystems applies, namely locations rather remote from NO_x sources with quite low concentration levels, which exceed the limit value only in rare situations. Therefore it is proposed that for **NO_x** the same range should be used as for NO_2.

PM2.5 data are at present not sufficient to allow a discussion of their representativeness. As concentration range for the representativeness of PM2.5, a value of 75% of the range used for PM10 is proposed, based approximately on the average PM2.5/PM10 proportion observed at different types of monitoring sites.

4.3.3.1 Discussion of the threshold values

The threshold values in Table 20 are, of course, a deliberate choice, which applies also to the area of representativeness. Extending the area of representativeness may be sensitive as regards the numerical value of the threshold, and changing the threshold criterion leads to differ-

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[16] Excluding some extraordinarily highly polluted monitoring sites in Macedonia and Bulgaria.

ent areas of representativeness. The sensitivity of the area of representativeness to the threshold values listed in Table 20 is tested in the validation procedure in chapter 7.5 for Austrian monitoring stations.

A possible way to check the appropriateness of the thresholds could be to compare measurement sites which clearly fall into different classes, e.g. to compare regional background with rural and urban background sites located not too far away from each other (within a distance of 100 km, and with similar climatic and topographic conditions). For this situation not only the classification parameters for emissions and dispersion, but also the comparison of concentration parameters should indicate that the sites are different. If the site can only be distinguished from the classification parameters, but not by the difference in concentration, the class size (in terms of concentration) may be considered too large.

The validation (chapter 7.5) shows that for PM10 and ozone (see chapters below for details) the concentrations are spatially quite similar, with the classification of emissions and the dispersion situation becoming a more stringent criterion for delimiting the representative area.

Testing the sensitivity to the numerical concentration thresholds shows that in most cases a larger concentration range does not extend the area of representativeness, because then the other criteria – emissions and dispersion situation, see chapter 4.3.4 –become the more stringent limitations.

The validation (chapter 7.5) shows that for PM10 and ozone (see chapters below for details) the concentrations are spatially quite similar, with the classification of emissions and the dispersion situation becoming a more stringent criterion for delimiting the representative area.

The results of the validation (chapter 7.5) suggest that the threshold values given in Table 20 are – in combination with the criteria for common reasons for similar concentration levels – of a reasonable magnitude for delimitating reasonable representativeness areas. For PM10 and ozone, lower thresholds may be considered.

Using the concentration range between the 10- and the 90-percentile of observed concentration from all European (i.e. AirBase) stations was discussed for deriving the concentration range used to define representativeness. This approach would leave out extreme values, which might be „representative" only of small areas.

The 10-percentile of the annual mean NO_2 concentrations is about 10 µg/m³ and the 90-percentile about 50 µg/m³, which means that those 10 % of the monitoring stations with the highest pollution levels cover 50 % of the total concentration range in Europe. The 10-percentile of the PM10 daily mean 90.4 percentiles is about 25 µg/m³ and the 90-percentile about 50 µg/m³, which represents less than one third of the absolute maximum. The 10-percentile of the 93.2 percentiles of the daily 8-hour maximum ozone concentrations is about 90 µg/m³ and the 90-percentile between 130 µg/m³ (2002) and 254 µg/m³ (2003).

Thus, the concentration range between the 90- and 10-percentile is about 40 % of the total range for the annual mean NO_2 values, and approximately 25 % for the PM10 daily mean 90.4 percentiles and 93.2 percentiles of the daily 8-hour maximum ozone concentrations, respectively.

However, there are two reasons why this approach was not adopted:

- When using the concentration range between the 10- and 90-percentile of the AirBase stations as reference, another decision would be required as to how many „concentration classes" should fit into this range. This decision (for example 10 %, which would yield comparatively small concentration ranges for the criterion of representativeness, or any other number) would be as arbitrary as the 10 % of the total observed concentration range.

- The assessment of representativeness shall cover all types of locations in Europe, including sites with very high and very low pollution levels. Therefore, a reference to the total observed concentration range seems justified.

4.3.3.2 Remarks on PM10

The quite close correlation between the annual mean and the 90.4 percentile of the daily mean values of PM10 (see chapter 7.2.3, Figure 59) suggests using only one of the two concentration parameters for an assessment of the representativeness of PM10 monitoring stations.

Applying the concentration ranges given in Table 20, the criteria are fulfilled equally for both parameters at almost all Austrian monitoring stations (chapter 7.2.2).

If a larger concentration range is applied, however, there are many cases where only one of the concentration criteria for PM10 is fulfilled (chapter 7.5).

It can be concluded that in the case that the thresholds given in Table 20 are applied, only one PM10 concentration parameter can be used – it is recommended that the annual mean should be used – or otherwise both parameters.

4.3.3.3 Remarks on Ozone

As a parameter to delimitate the representative area for ozone, the AOT40 (May-July), which is used as target value for the protection of vegetation according to Directive 2002/3/EC, was also taken into consideration. It was decided not to use the AOT40 for the following reasons:

- the calculation of this parameter is much more complicated than a „simple" average or percentile;
- the statistical relation between the AOT40 and the 93.2 percentile of the daily maximum 8-hour mean value – presented in Figure 4 for Austria – shows a quite close correlation between the two parameters. Therefore it can be expected that the AOT40 as an input parameter for the determination of the area of representativeness will give quite similar results to those obtained with the 93.2 percentile of the daily maximum 8-hour mean values.

The coefficient of determination (R^2) for three different regression curves (linear, quadratic, potential) is between 0.87 and 0.90. Monitoring sites with large deviations from the regression curves show no systematic pattern and cover various types of locations – different altitude, north and south of the Alps.

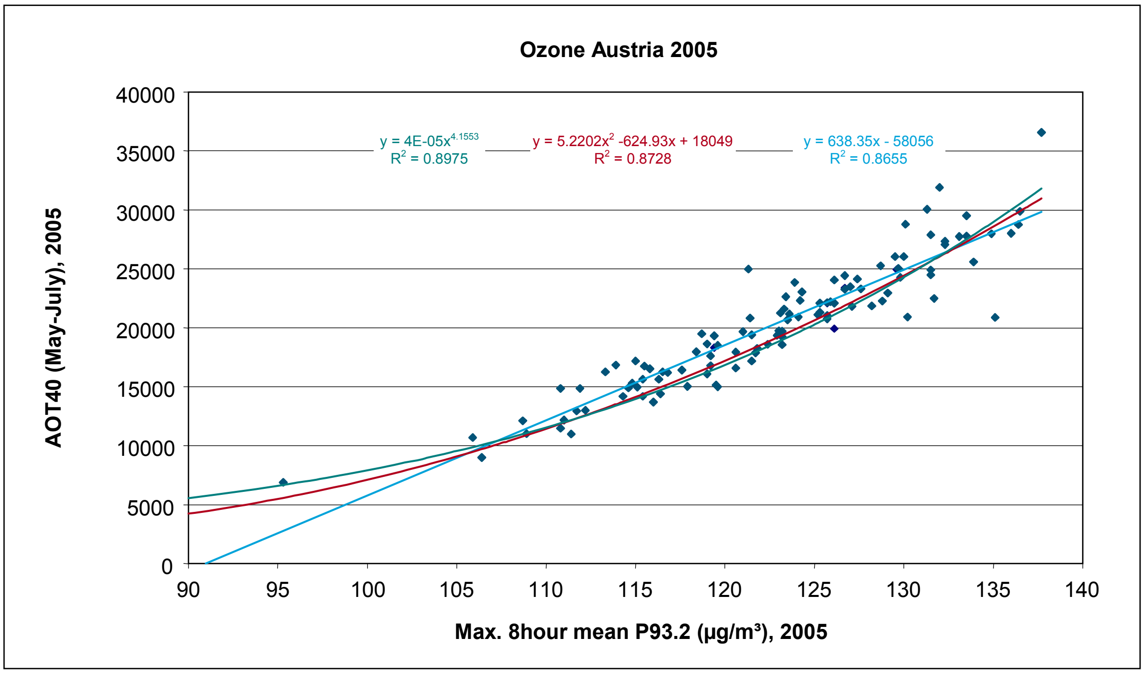

Figure 4: Relation of annual AOT40 (May-July) to the 93.2 percentile of the daily maximum 8-hour mean values, Austria, 2005. Regression curves: blue linear, red quadratic, green potential.

4.3.4 Criteria of common reasons for similar concentrations

As outlined in chapter 4.2.3, the following external parameters have to be assessed as „common reasons" for similar concentrations:

- emissions;
- dispersion situation;
- atmospheric transport and transformation.

Emission sources: We propose that a monitoring station is representative of a location only if the station and the location are in the same class with regard to emission sources. The „emission source" classes are defined in chapter 4.4. In this chapter a guideline is given on how to determine the „emission source" class of a location.

We will test the **dispersion situation** as an additional criterion. We propose that a monitoring station is representative of a location only if the station and the location feature a similar dispersion situation. The dispersion situation in this context is related to the topographic/geographic situation and the local building structure/street geometry which trigger the dispersion/accumulation of pollutants.

The dispersion situation covers various scales:

1. Local situation: street geometry, forests, and local terrain;
2. Regional topographic situation;
3. Topographic situation influencing the regional to meso-scale flow and climate.

The monitoring station and the location in question have to feature the same topographic and climatic features as proposed in chapter 5.3.

Criteria related to atmospheric transport and transformation characterise

- the speed of pollutant transport on a regional scale – related to the wind speed in the mixing layer – and
- the time scale of chemical transformation in the atmosphere.

The chemical transformation of air pollutants – which means both removal and formation – of the major pollutants considered in this study (NO_2, PM10, Ozone) covers a temporal scale of less than one day. Related to an average atmospheric lifetime of about 12 h for NO_2 (which also represents the time scale of the formation of particulate ammonium nitrate as a major constituent of PM10 and PM2.5) and the transport velocities in the mixing layer, the corresponding spatial scale is the average travelling distance of air masses in the mixing layer over 12 h. This distance is considered the **maximum extension** of the area of representativeness of a monitoring station.

For the extra-Alpine parts of Austria, the respective distance is about 100 km, derived from an analysis of backward trajectories (chapter 5.4).

This distance may of course vary, depending on wind direction as well as on the geographical location in Europe with higher wind speeds in the oceanic climate and lower wind speed in the Mediterranean and continental climate.

To summarise: A monitoring station is representative of a location if:

- The statistical parameter for the respective pollutant differs, over three years, by less than half of the concentration range given in Table 20.
- The monitoring station and the location are in the same classes with regard to emission sources (see classification, chapter 2).
- The monitoring station and the location feature a similar dispersion situation (see chapter 5).
- The area of representativeness is restricted to a maximum distance.

5 METHODS TO DETERMINE THE REPRESENTATIVE AREA

In principle, the representative area is determined by applying the definition (see chapter 4) to points in space and determining if all criteria are fulfilled or not.

According to the definition, the following information is required to determine the representative area:

- Pollutant concentration (chapter 4.2.2)
- Emissions (chapter 4.2.3)
- Dispersion situation (chapter 4.2.3)
- Maximum distance (related to atmospheric transformation) (chapter 4.2.3).

For the assessment of representativeness, information on AQ has to be, in principle, determined for all points in space. As the second step, the area for which the criteria for representativeness are fulfilled has to be delimited.

Chapter 5.1 outlines the sources of information on the spatial distribution of the pollutant concentration, and the following chapters discuss the reasons for similar concentrations (according to chapter 4.2.3).

5.1 Spatial information on pollutant concentration

The first step of the assessment of the area of representativeness is a comparison of the concentration(Table 20) at the respective monitoring station with, ideally, the concentration at any location in space, for three years.

Spatial information about AQ can be obtained by various means, which are given, together with advantages and disadvantages, in Table 21.

To determine the pollutant concentration at all points in space, there are in principle two possibilities:

1. determining the pollutant concentration using air quality modelling;
2. determining the pollutant concentration based on surrogate data which are spatially available themselves.

An assessment of the concentration distribution based on surrogate data can in fact be seen as a simple modelling technique.

The criteria for the concentration parameters given in chapter 4.3 have to be applied to the modelled concentration data or the data obtained by use of surrogate information (see chapter 5.1.2).

Additional measurements (i.e. measurement campaigns, such as passive sampling which is often recommended because of the lower costs compared to automated measurement) at several suitable points in the surroundings of the monitoring station (and interpolation of the measured values), often recommended to obtain spatial information on air quality, are in fact not really sufficient to provide a complete spatial representation of pollutants throughout the territory of a MS. Additional measurements provide a denser monitoring network, although no complete spatial coverage. Despite the lower costs, any compromise between costs, spatial coverage and density of additional measurements limits either the territory covered or the density of the measurement points. Nevertheless, additional (passive) measurements can provide additional information on the spatial concentration distribution and can be used to establish relations between surrogate data and concentration values. The advantages and disadvantages are listed in detail in Table 21 and discussed in chapter 5.1.3.

Table 21: *Methods for acquiring spatial information on AQ.*

Method	Advantage	Disadvantage
Additional (temporal) measurements	Accuracy of continuous measurement	Limited spatial resolution Limited temporal resolution of passive sampling Limited accuracy of passive sampling
Modelling	Spatial coverage and resolution Flexibility Easy to cover several pollutants	Limited spatial resolution (depending on the model resolut) Resource intensive Depending on input parameters (emissions, meteorology) Shortcomings of model accuracy, especially regarding PM
Estimation based upon surrogate data (emissions, dispersion situation)	Spatial coverage Easily available („cheap”)	Limited accuracy based on statistical analyses and expert judgement

5.1.1 Modelling

The assessment of representativeness based upon modelling has to take into account:

- Spatial resolution of the model
- Temporal resolution of the model – does the model yield (only) mean values or information about the temporal variation?
- Duration of the modelled period/episode

The assessment of representativeness based upon modelling requires the availability of appropriate models, input parameters and skilled experts.

Various kinds of air quality models are used to obtain a spatial representation of the concentration field.

According to the Directive 1999/30/EC Annex VI sampling points directed at the protection of human health should be sited to provide data on the areas within zones and agglomerations where the highest concentrations occur to which the population is likely to be directly or indirectly exposed for a period which is significant in relation to the averaging period of the limit values; and to provide data on levels in other areas within the zones and agglomerations which are representative of the exposure of the general population.

HARTMANN AND GEIGER (2005) discuss, by using the example of the monitoring network in North Rhine-Westphalia, Germany, how these requirements may be fulfilled using air quality modelling. Screening model runs are conducted in an iterative process (ambient air concentration caused by traffic with the model IMMIS, background concentrations from the air quality network and from EURAD model simulations) for the whole region in order to identify hot-spots. The highest ranked sites are investigated concerning the exposure of population near-by and the building configuration (street canyons) and finally, temporary measurements are conducted to compare the pollution levels at the most likely hot-spots.

LOHMEYER ET AL. (2005) also present examples where regional to micro-scale air quality modelling is used to support the monitoring network design in urban areas, e.g. in the city of Hannover (see below). The model results give clues for the positioning of monitoring stations. Screening calculations of PM10 concentrations due to traffic for an urban street network can be used to identify locations which are most appropriate to monitor threshold exceedances. More complex dispersion models are also used to extend point measurements to aerial distribution and to supplement data with respect to their spatial and temporal representativeness. When model results and measurements are combined, model sensitivity to the reliability of input parameters as well as model uncertainties (approximations, model configuration etc.) need to be considered as much as the correctness of the measurements.

SCHATZMANN et al. (2005) give an overview of the activities conducted under the acronym VALIUM in Germany. A system of consistent coupled numerical models M-SYS (meso- and microscale meteorological and chemistry transport models) is developed as a tool for the implementation of European urban air quality regulations. A consortium was formed, which consisted of five German research institutes, environmental consultants and an environment agency devoted to the generation of a set of high quality data for the validation of the numerical model system. The validation data are based on a combination of field studies, tracer experiments and corresponding ten wind tunnel experiments. The field experiments were carried out inside and around a street canyon in a city district of Hannover, Germany.

The study showed that about one third of the variance of the NO_x concentrations measured at a rooftop station was caused by regional transport, whereas at ground level this dependence was not found. For PM10, large differences in concentrations between ground and rooftop level were shown. The study concluded that concentrations measured at rooftop level are representative of the surrounding city district.

Modelling as a basis for the assessment of representativeness is discussed and recommended in KUHLBUSCH (2006).

PARAMONOV (1997), FRICKE et al. (2000) and VANA (2002) apply trajectory statistics to quantify the variability between and the representativeness of stations based on long-time model runs (several years to decades). Eulerian photochemical models are used and compared to measurements as well as to other model results e.g. by TILMES et al. (2002) or MONTEIRO et al. (2005).

SCAPERDAS et al. (1999) and SCHLÜNZEN et al. (2003) deal with high-resolution simulation of flow structures and dispersion patterns (e.g. in street canyons) using a computational fluid dynamics (CFD) code. The validation and the quality of today's applications of urban dispersion models is discussed by SCHATZMANN & LEITL (2002). The authors point out that model results may differ highly due to different choices of boundary conditions, turbulence closure schemes and model configuration as found in model comparison experiments. Quality assurance procedures and suitable data-sets for validation are therefore needed. COST Action 732 is devoted to these tasks.

In general, it should be noted that air quality modelling is associated with considerable costs. In most cases, no model results are available and models would have to be implemented specifically for determining the representative area. Therefore, alternatives to modelling are discussed in the following.

5.1.2 Estimation and parameterisation of concentrations

Parameterisation of concentrations means a simple kind of modelling which uses statistical or semi-empirical relations between several external parameters and pollutant concentrations. It is in fact a surrogate for modelling for areas where no model data (at appropriate spatial resolutions) are available.

Input data for the parameterisation of concentrations can be

- **emission data** (emission densities), or surrogate data for emissions (such as traffic information or population density),
- **parameters triggering dispersion: meteorological** or climatological data, **topographical**/geographical information, **building** structure, etc. (see chapter 5.2 and 5.3).

Obviously, these data also serve as input for modelling.

If available, measurement data can be used and interpolated or extrapolated using relations of concentrations e.g. with emissions or altitude.

As stated in chapter 2, the input data which can be used to estimate the pollutant concentration (so-called „surrogate data”) are also input data for the determination of the representative area, because they are criteria for „same reasons” for the pollution level. Therefore, if no measured or modelled concentration data for a sufficient spatial coverage are available, the input for the determination of the representative area may be reduced to emissions, dispersion situation and, if available, some measurement data. Chapter 5.6 will deal with the assessment of the spatial distribution of the relevant concentration parameters (annual mean, percentiles) based upon surrogate data – emissions, dispersion situation, (measured) background concentrations – on different levels of sophistication.

Common classification schemes for monitoring stations (e.g. EoI, AIRBASE) make use of surrogate data which characterise various parameters which themselves influence the pollutant concentration and its temporal variations.

Criteria for the selection of surrogate data – apart from their ability to characterise measurement data – include

- availability (e.g. from emission inventories, geographical data sets, traffic census, personal observation, …);
- spatial coverage and spatial resolution;
- effort of data handling (number of parameters).

Operational applications of surrogate data have been, for example, developed for Toronto and Switzerland. Surrogate data can also be used as (additional) input for dispersion models. Surrogate data is used, e.g., in land use regression models (e.g., JERRET ET AL. 2003) and in the PM concentration model for Switzerland (WEBER 2003).

The land-use regression model for Toronto (JERRET ET AL. 2003) determines pollutant concentration at a certain location as a function of land use types within circular areas (buffers) around this location. For this approach, a total of 85 independent variables were applied covering the following categories: land use, road and traffic, population, physical geography, and meteorology. These variables were available as two-dimensional data („surrogate data”) from various sources (e.g. traffic count, street width, wind direction etc.).

In the study of JERRET ET AL. (2003), NO_2 concentration data from 94 passive sampler locations was used to identify those variables which were highly correlated with NO_2 concentrations. Using seven of these variables (e.g. a measure of traffic counts within a radius of 500 m, density of resident population within 2000 m), NO_2 concentrations were calculated at a high resolution for the area of the city of Toronto. The resulting map presents much more detailed information than maps based on interpolation of measured concentrations only.

The model for PM concentrations in Switzerland (WEBER 2003) uses a simple dispersion model based on emission inventories with a resolution of 200 m. In order to obtain emission inventories at such a high spatial resolution, total national emissions were spatially disaggregated using surrogate data: Emissions from industry, commercial sources, construction, agriculture and forestry were disaggregated according to their corresponding land use categories, which were available for the whole area of Switzerland. Residential emissions were disaggregated based on population density. Traffic emissions were based on national road traffic models.

To summarise, surrogate data such as land use type, traffic volume or population density can be used to assess pollutant concentrations either

- based on correlations between surrogate data and measured concentrations (e.g., JERRET ET AL. 2003) or
- by creating high-resolution emission inventories based on surrogate data and conducting dispersion modelling.

5.1.3 Additional measurements

The assessment of representativeness by additional (temporal) measurements is discussed in the literature for various applications. An example of such a study is shown in chapter 7.2.7. In most cases local/regional sampling campaigns are recommended.

The major disadvantage of additional measurements – even performed by cheap equipment like passive samplers – is the limited spatial resolution versus spatial coverage. The limited number of sampling points restricts additional measurements either to small areas with high spatial coverage or to a coarse network over a larger area.

Passive sampling measurement campaigns for determining representativeness areas are therefore usually restricted either

- to grid monitoring designs in order to determine background concentrations, or
- to selected locations with different environment (with respect to emissions and dispersion situation), the representativeness of which has to be determined by additional surrogate information.

A specific problem of measurements by passive sampling is the very limited temporal resolution and poor accuracy, especially for high NO_2 concentrations.

Table 22: Methods for assessment of representativeness by measurement.

Method	Reference literature
Local/regional sampling campaign in the vicinity of a monitoring station	BLANCHARD ET AL. (1999) KIM ET AL. (2005) LEBRET ET AL. (2000) CHAN & HWANG (1995) UMWELTBUNDESAMT (2006a) FVT (2006)
Comparison of several monitoring stations	VAN DER WAL ET AL. (2000) WILSON ET AL. (2005) KIM ET AL. (2005)
Interpolation between several monitoring stations	KNODERER (2004)

The recommendations for the operational procedure given in this study will not focus on additional (passive sampling) measurements.

5.1.4 Time period

Since the characteristics of the pollutant concentration may change over time due to changes e.g. in emissions or building structure[17], the classification of monitoring stations can change over time, and it might be misleading to use long time series over many years for the classification and assessment of the representativeness of a monitoring station.

Classification as well as the assessment of representativeness should therefore be repeated after some years or if the emissions have changed significantly.

On the other hand, the meteorological influence might lead to an inter-annual variation of the concentration field which induces changes in representativeness from one year to another. Therefore an analysis of data from three years – as proposed – seems appropriate.

5.1.5 Spatial scales

The area of representativeness of a monitoring site may represent quite different spatial scales. In general, three scales can be distinguished:

- regional scale – outside of settlements and remote from roads;
- urban scale;
- road scale.

Areas with a significant impact from industrial emissions may constitute separate small-scale areas.

In most cases, monitoring sites and their area of representativeness can be assigned to a distinct scale. Of course, the area of representativeness can cover several non-contiguous areas.

The input data necessary to assess the area of representativeness depend on the spatial scale. This is obvious for model data, for with the spatial resolution must correspond to the respective scale – for example, a model resolution much larger than 10 m is not sufficient to identify the representative area of roadside monitoring stations.

Table 23 lists input data which can – besides model results – be used for the delimitation of representative areas for different scales.

Table 23: Input (surrogate) data for the assessment of representativeness on different spatial scales.

Regional scale	Topographic/geographic information/map at the appropriate resolution Corine Landcover EMEP emissions
Urban scale	Topographic/geographic information/map at the appropriate resolution Population distribution Corine Landcover Emission inventory at the appropriate resolution
Road scale	High resolution map of buildings High resolution road map TeleAtlas roads Emission inventory at the appropriate resolution

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[17] local dispersion conditions

5.2 Emission class and surrogate data

To fulfil the representativeness criteria, a location has to be in the same **emission class** – as derived according to chapter 2 – as the investigated monitoring station.

This means that the delimitation of the area of representativeness is directly related to the class boundaries.

This would, ideally, require the classification of the whole territory. This is fairly practicable where emission inventories are available, but inventories are limited with regard to spatial resolution.

Similar to the different levels of sophistication of the input data for the classification of local road traffic emissions (chapter 3.2.3), domestic heating emissions (chapter 3.2.4) and industrial emissions (including commercial areas, airports and ports) (chapter 3.2.5), input data for the emission classification of the whole territory are available at different levels of sophistication and accuracy; these are listed in Table 24.

5.2.1 Traffic emissions

If the classification of the investigated monitoring station is determined as „low traffic influence", the representative area is located within areas remote from the major road network.

If the classification of the investigated monitoring station is determined as „medium" or „high traffic influence", the major road network has to be screened – using emission inventory data or traffic census data – according to the classification criteria. An extension of the representative area on the sides of major roads depends on the emissions at the respective road.

If neither emission inventories nor representative traffic census data are available, TeleAtlas[18] information up to „functional road class" 3 can be used.

An evaluation of the relation between the road traffic classification parameter and the length of TeleAtlas roads up to FRC 3 is given in chapter 6.5.11.

5.2.2 Emissions from domestic heating

After determining the classification of the investigated monitoring station, the spatial distribution of domestic heating emissions (from emission inventories) or – as a surrogate – the population is screened.

5.2.3 Industrial emissions

After determining the classification of the investigated monitoring station, the location and emissions from industrial and commercial sources, including power plants, ports and airports, have to be screened.

If Corine Landcover (CLC) is the only available information, the identification of „Industrial or commercial units", „Airports", and „Port areas" can be used as a proxy for industrial activities; for PM10, also „Mineral extraction sites", „Dump sites" and „Construction sites" can be of interest. Anyhow, it should be noted that CLC data do not give any information about real emissions (see also chapter 6.5.10).

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[18] © 2005 Tele Atlas N.V., © BEV, GZ 1368/2003

Table 24: Input data for the spatial assessment of the emission class for local road traffic, domestic heating and industry on different levels of sophistication.

	Road traffic	**Domestic heating**	**Industry**
High level	Streets in emission inventories	Highly resolved emission inventories	Highly resolved emission inventories, Modelling
Medium level	Traffic census + emission factors, extrapolated to the whole major road network	Population distribution + emission factors	Land use data (minor sources), information about large point sources (e.g. EPER) + estimate of local impact
Low level	Geographical information of major road network, e.g. TeleAtlas	Population distribution	Land use data

5.3 Dispersion situation

The influence of the dispersion situation discussed here covers the meteorological and topographic influence on the observed pollution level. The dispersion situation triggers the extent to which emissions – at different distances from the monitoring site – contribute to observed concentrations.

For the assessment of the dispersion situation, the required data are geographical and meteorological parameters.

Three scales shall be considered, which are listed in Table 25.

The criteria for the local environment only apply to traffic related monitoring sites, since they determine the emission of locally emitted pollutants. They are of only minor importance for background sites.

Whether the local environment is relevant for the dispersion of industrial monitoring stations has to be decided individually for the respective monitoring site.

Table 25: Dispersion situation relevant for the assessment of representativeness.

	Scale	**Influence of ….**
Local environment	<100 m	Street geometry, local building structure and topographic situation, forest
Regional environment	<10 km	Valleys, basins, plains
Large-scale	>10 km	Large-scale topographic and climatic region

5.3.1 Local environment

Different types of local dispersion situations are listed in Table 26. For monitoring stations in the immediate vicinity of emissions, i.e. roadside locations, and, perhaps, industrial sites, a finer classification is necessary than for background sites. For background sites, a simplified classification of the local dispersion situation – differentiating between built-up or forested areas and flat areas – is proposed.

A „*street canyon*" represents – usually urban – locations with high compact buildings at each side of the road. A minimum ratio between the height of the buildings and the width of the street is proposed as criterion for „street canyon". The height of the buildings has to be averaged over some 100 m along the street and on both sides.

Locations with compact high buildings at only one side of the street and situations with very wide streets which do not fit the height/width-criterion for „street canyon" are classified as „*one sided compact buildings*". Such types of location can cover major roads in large cities with lawns, underground lines or rivers between lanes.

The class „*detached buildings*" covers locations with buildings in a vicinity of some 10 m around a monitoring site which do not fit the criterion for „street canyon". The distance up to which buildings have to be taken into account depends on their size. The classification should actually be based on expert estimation and related to model results.

Groups of trees or a *forest* can exert an influence on local dispersion which is similar to that from buildings. Therefore monitoring sites in the vicinity of large compact trees or forest – which might be part of an adjacent park – are to be classified accordingly.

„*Flat terrain*" covers all situations with no major buildings and trees in the vicinity of the monitoring site.

„*Exposed*" situations represent locations with favourable dispersion due to a higher altitude on a slope or ridge. The relative altitude of „exposed" locations has to be assessed by experts; no quantitative criterion which could be applied throughout Europe can be derived. Altitudinal differences are, as stated above, more critical in regions with a more adverse large-scale dispersion situation, i.e. in valleys and in basins with continental climate rather than oceanic climate.

Table 26: Classes of local environment.

Local environment for traffic and industrial stations		**Local environment for background stations**
Street canyon	Monitoring site in a street with compact (high) buildings at each side of the street (example Figure 6) A „street canyon" is considered to be a road with a minimum ratio of 0.5 between the height of the buildings (related to the average over 100 m street length or more) and the width of the street.	built-up, or forested areas (example Figure 11)
Detached buildings or one-sided compact buildings	Detached buildings in a vicinity of up to about 10 m (example Figure 8), or compact buildings at one side of the street (example Figure 7)	
Flat terrain	Flat terrain (free air flow) without large buildings and forest up to at least several 10 m (example Figure 9)	Flat and open terrain (example Figure 12)
Exposed terrain	Location on a slope or ridge of a hill (example Figure 10)	

For an assessment of the local environment, information about street geometry, building structure, forests and local topographic situations is required.

5.3.1.1 Concentration gradients along roads with varying building geometry

To assess the influence of buildings along a street – as a basis of the above listed classes of local environment – simulations of pollutant dispersion have been conducted for „typical" situations:

- wide street: 4 lanes, 10 m open space at each side of the roadway (which could be a footpath, lawn, parking area, ….);
- street canyon: 2 lanes, 2 m opean space (footpath) at each side of the roadway;
- street canyon: 4 lanes, 2 m opean space (footpath) at each side of the roadway.

The following building types are simulated:

- compact buildings 10 m high at both sides of the road;
- compact buildings 20 m high at both sides of the road;
- one-sided compact buildings 10 m high;
- one-sided compact buildings 20 m high;
- detached buildings 10 m high at both sides of the road; the length of the buildings is 20 m, as well as the space between them;
- detached buildings 20 m high at both sides of the road; the length of the buildings is 20 m, as well as the space between them.

A simulation of the concentration has been conducted with the Lagrangian Particle Diffusion Model LASAT, version 2.14 (Janicke 2004, 2005). The simulation was performed for an inert pollutant, which means that NO to NO_2 conversion was not considered. LASAT (Lagrange Simulation of Aerosol – Transport) is a model to simulate the dispersion of atmospheric trace gases. A cluster of particles which represents a special amount of air pollutants is translated along a trajectory and turbulent diffusion is simulated with a random process. LASAT is consistent with the VDI directive 3945 (part 3, particle model) (VDI 2000) and is the basis of the dispersion model AUSTAL 2000.

The related diagnostic wind field model simulates the air flow around buildings and the recirculation zone on the lee side of buildings using empirical approaches. Manifold building structures (approximated by a frequency polygon) can be considered.

The simulation covers the following meteorological conditions:

- wind parallel to the road
- wind at 45 ° to the road
- wind at 90 ° to the road
- stable and unstable dispersion situation.

Concentrations were calculated for winds at 0 °, 45 ° and 90 ° to the road, at both sides, in order to cover both the windward and leeward side.

The information retrieved from the simulation, which is used to assess the influence of different types of buildings along the road is the ratio of the concentration for a certain street/building geometry compared to the situation with no buildings, i.e. flat, opean terrain.

The results listed in Table 27 are the averaged over stable and unstable dispersion situations, the three wind directions, and the windward and leeward side.

Table 27: Concentration ratio for different street geometries compared to flat terrain.

	Street canyon		**Wide street**	
	4 lanes	**2 lanes**		
Distance from kerb	1 m	1 m	1 m	9 m
Compact buildings, 10 m high, at both sides	25.1	12.8	4.4	35.0
Compact buildings, 20 m high, at both sides	23.4	14.4	4.1	29.9
Compact buildings, 10 m high, at one side	10.2	4.8	2.7	14.1
Compact buildings, 20 m high, at one side	16.0	4.7	3.8	18.9
Detached buildings, 10 m high, at both sides	12.0	5.0	2.4	13.5
Detached buildings, 20 m high, at both sides	12.5	5.1	3.2	19.7

In flat terrain, the concentration is zero on the windward side of the street, and any building causes a large increase due to a leeward vortex behind the windward buildings.

The – possibly surprising – result is that the highest impact of buildings in general occurs near the building façade at wide streets. At a distance of 9 m from the kerb, pollutants are quite diluted on the leeward side in flat terrain, and this building configuration causes a huge increase in concentrations.

Compact buildings cause a comparatively large increase in concentration compared to flat terrain.

Averaged over both sides of the streets and all wind directions, the impact of one-sided compact buildings is quite similar to that of detached buildings at both sides.

The height of the buildings is of minor influence; the impact of 20 m high buildings is less than 10% above that of 10 m high buildings at a narrow street. (At a wide street, 10 m high buildings have a bigger effect than 20 m high buildings, which may be due to nonlinear effects in the leeward vortex.)

5.3.1.2 Wien (Vienna) – „Multi-purpose map"

As an example, the urban administration department MA41 „uban surveyors" of Wien (Vienna) provides a „multi purpose map", a very detailed map comprising, beside other information, the height and length of each individual building. This map enables a very precise visualisation of the building structure along each street.

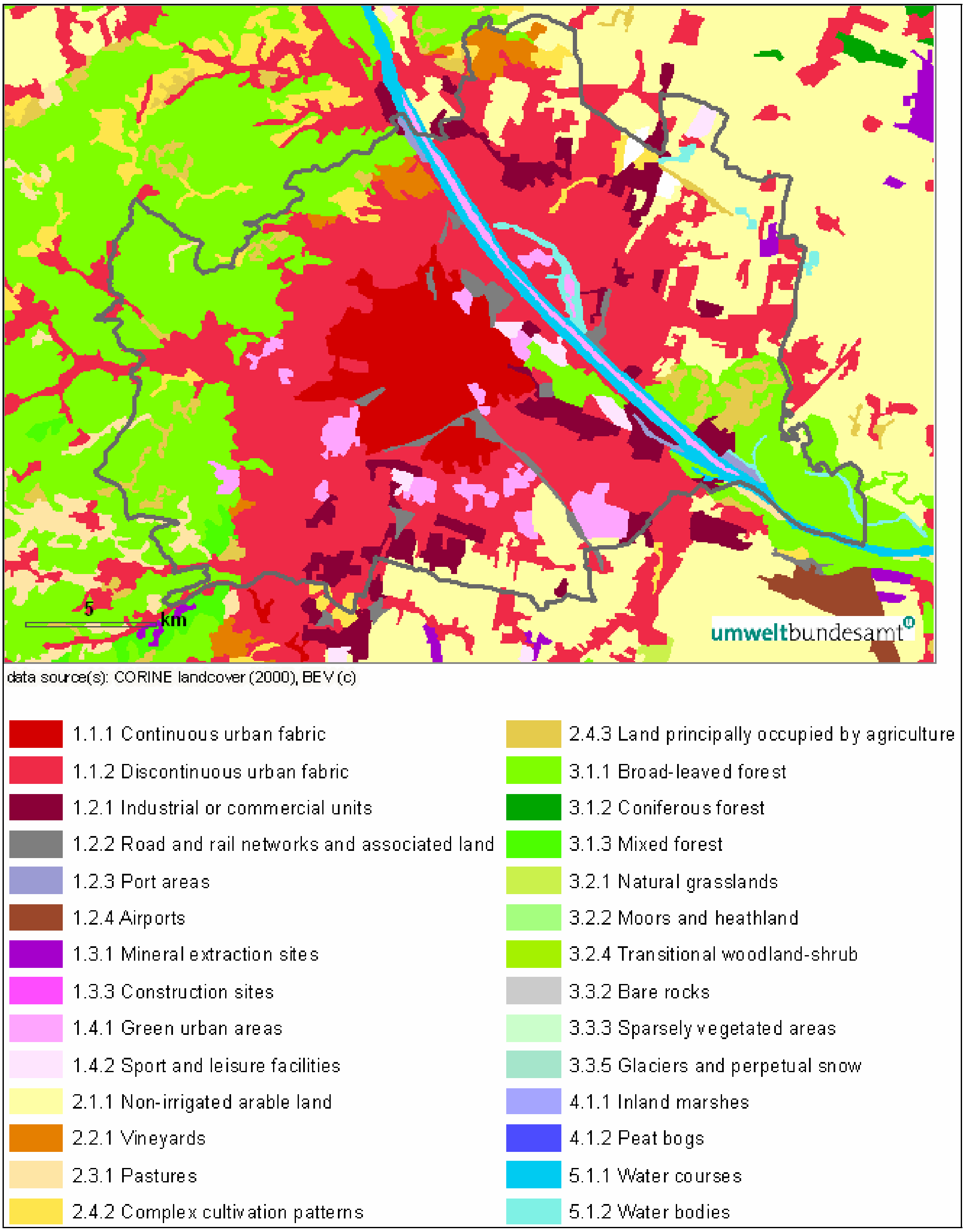
It is not possible to make detailed proposals for applications of the „multipurpose map" within the present study, as the data are very costly and available for testing in small areas only.

If such detailed information is not available, an assessment of detached built-up and forested areas should be based upon detailed maps drawn to a scale of 1:50,000 or finer.

5.3.1.3 CORINE Landcover

CORINE Landcover (CLC) data may be used as an approximation for the building structure or the local environment on a scale of 100 m; nevertheless, the limited representation of 25 ha (equal to a square 500 m x 500 m) has to be considered.

As an approximation, locations within CLC class 1.1.1 „continuous urban fabric" can be classified as „street canyon", CLC class 1.1.2 „discontinuous urban fabric" as „detached buildings".



data source(s): CORINE landcover (2000), BEV (c)

Figure 5: Corine Landcover map of Wien (Vienna).

Figure 6: Street canyon, Taborstraße, Wien, Austria (Source: MA22, Wien).

Figure 7: One-sided compact buildings (Spittelauer Lände, Wien, Austria), Metro line and Donaukanal (Danube Canal) at the left.

Figure 8: Detached buildings, Kufstein Praxmarerstraße, Tyrol, Austria (source: Amt der Tiroler Landesregierung).

Figure 9: Flat terrain (free air flow) without large buildings and forest up to several tens of metres, Gärberbach A13, Tyrol, Austria (source: Amt der Tiroler Landesregierung).

Figure 10: Location on the slope of a hill, industrial site, Hallein Winterstall, Salzburg, Austria (source: Amt der Salzburger Landesregierung).

Figure 11: Backgound site, built-up or forested area, Köflach, Steiermark (Styria), Austria (source: Amt der Steiermärkischen Landesregierung).

Figure 12: Background site, flat and open terrain, Rennfeld, Steiermark, Austria (source: Amt der Steiermärkischen Landesregierung.)

5.3.2 Regional environment

A key factor for the relation between emissions and measured concentrations, as well as for local, regional and long-range transport is the regional scale topographic location of the monitoring site. The types of regional topographic environment on a scale of some 10 km which have to be distinguished are given in Table 28.

Table 28: Classes of regional environment.

Flat terrain (Figure 14)
Hilly terrain (Figure 15)
Mountainous terrain – slope (Figure 16)
Mountainous terrain – ridge, pass or summit (Figure 12)
High alpine terrain (Figure 17)
Valleys in hilly terrain (Figure 18)
Valley in mountainous terrain (Figure 19)
Basin in hilly terrain (Figure 20)
Basin in mountainous terrain (Figure 21)
Basin partly surrounded by mountains (Figure 22)
Coast with flat terrain in the interior (Figure 23)
Coast with mountainous terrain in the interior (Figure 24)

The availability of geographical information on the respective scale is essential for the accurate assessment of the dispersion situation and therefore for the delimitation of representative areas.

The delimitation of the different types of topographic units – *plain, valley, basin, hills, mountain* – should be performed manually using maps of appropriate resolution.

A mathematical procedure to delimitate such units based on digital topographic data has proved to be quite difficult, as it is not easy to give quantitative criteria for topographic features like valleys or basins (see e.g. LOIBL 1992).

The – horizontal and altitudinal – separation of flat areas, valleys and basins from elevated terrain should be the subject of expert estimation. Figure 13 shows the topography of Austria, covering altitudes from 110 m to 3797 m, which easily allows the identification of plains, hilly terrain, basins, valleys and alpine areas of different absolute altitudes.

No easy quantitative algorithm is available which identifies and delimits the above mentioned regional-scale topographic areas. Quantitative criteria might e.g. include relative differences in altitude both upward and downward within a certain distance around a certain location, or a combination of the average and the standard deviation of the altitudinal differences within a certain distance. In specific cases, the delimitation can be made by experts based on knowledge of the regional situation.

As stated above, the differences between different types of dispersion situations are more critical in regions with more adverse large-scale dispersion situations than in those with oceanic climate. No quantitative criterion applicable throughout Europe can be derived.

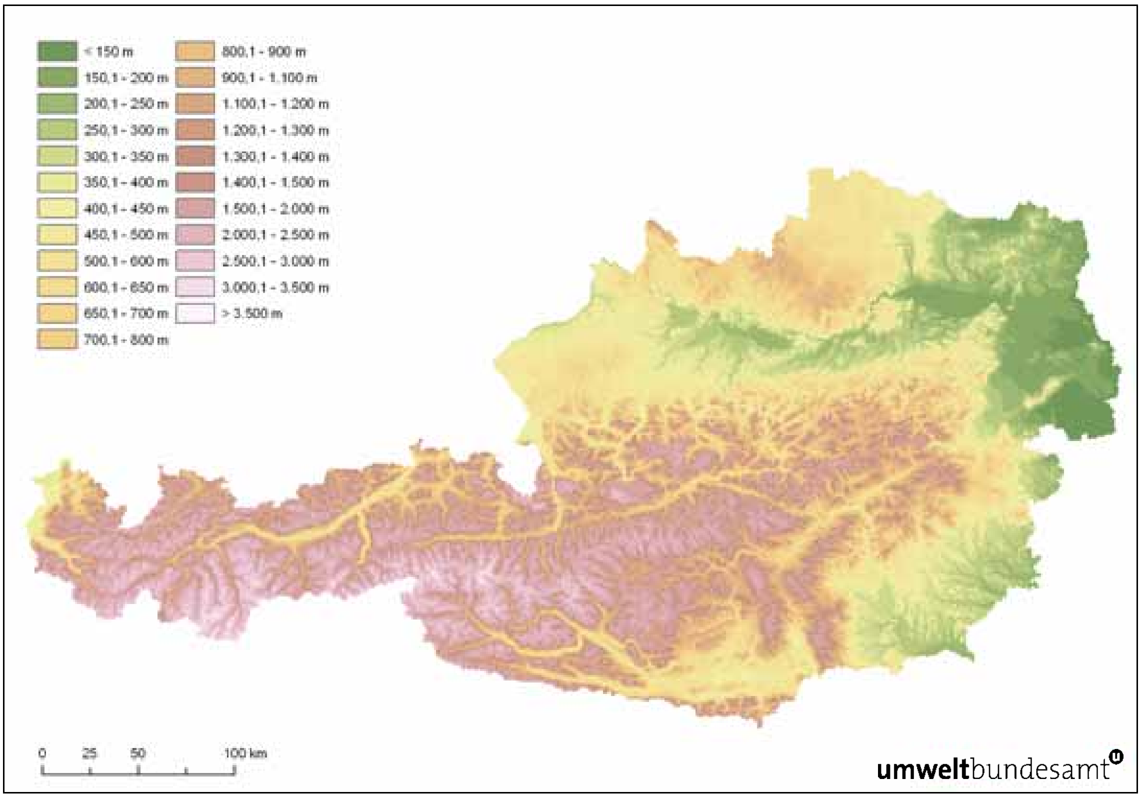


Figure 13: Topographic map of Austria.

Figure 14: Plain, Illmitz, Burgenland, Austria.

Figure 15: Hilly terrain, Klöch, Steiermark, Austria.

Figure 16: Mountainous terrain – slope, Vorhegg, Kärnten (Carinthia), Austria.

Figure 17: High alpine terrain, Sonnblick, Austria, 3106 m (Source: ZAMG).

Figure 18: Valley in hilly terrain, Ochogavia, Spain (Lorenz Moosmann).

Figure 19: Valley in mountainous terrain, Achenkirch, Tyrol, Austria.

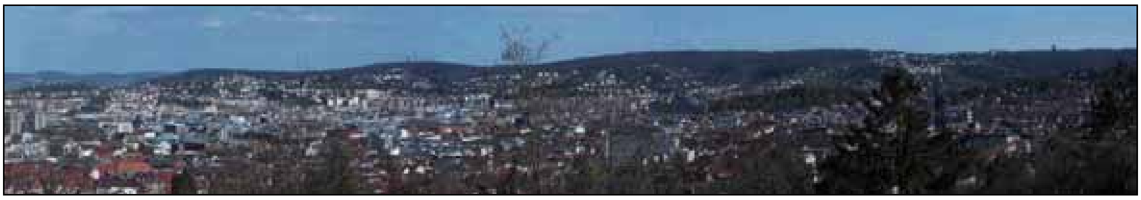


Figure 20: Basin in hilly terrain, Stuttgart, Germany[19]

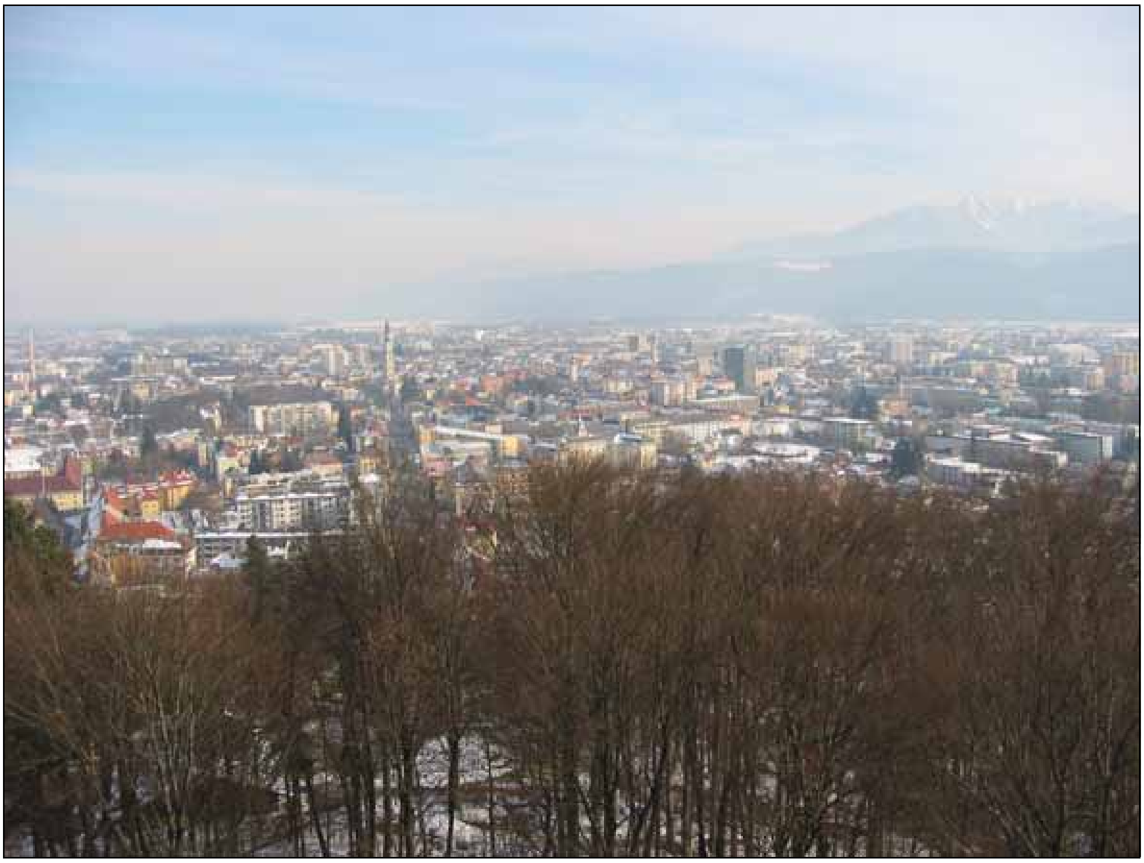


Figure 21: Basin in mountainous terrain, Klagenfurt, Austria.

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[19] This figure is based on the picture ***http://de.wikipedia.org/wiki/Bild:Stuttgart_Panorama_2007.jpg*** from the free media database „Wikimedia Commons" (***http://commons.wikimedia.org/wiki/Main_Page***) and is subject to the *terms of the GNU Free Documentation License* ***(http://en.wikipedia.org/wiki/GNU_Free_Documentation_License).*** The author of the picture is Roger Kreja.

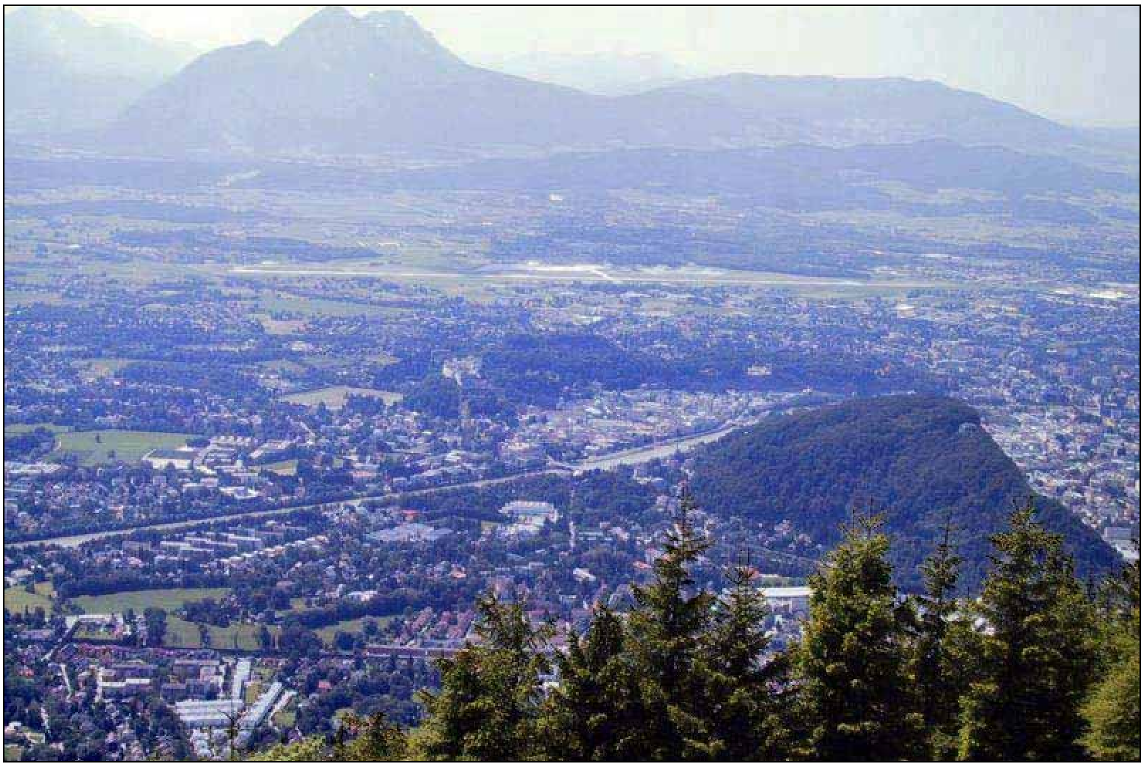

Figure 22: Basin partly surrounded my mountains, Salzburg, Austria[20].

Figure 23: Coast with flat terrain in interior, Warnemünder Strand, Germany[21].

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[20] This figure is based on the picture **http://de.wikipedia.org/wiki/Bild:Salzburg_vom_gaisberg.jpg** from Wikipedia, the free encyclopedia (**http://de.wikipedia.org**) and is subject to the *terms of the GNU Free Documentation License* ***(http://en.wikipedia.org/wiki/GNU_Free_Documentation_License).*** The author of the picture is Matthias Kabel.

[21] *This figure is based on the picture* ***http://de.wikipedia.org/wiki/Bild:Warnemuende_Strandpromenade_Hotel_Neptun.jpg*** *from the free media database „Wikimedia Commons" (**http://commons.wikimedia.org/wiki/Main_Page**) and is subject to the terms of the „Creative Commons Attribution ShareAlike 2.5" License. (**http://creativecommons.org/licenses/by-sa/2.5/e**). The author of the picture is the Wikipedia user Darkone.*

Figure 24: Coast with mountainous interior, Agios, Greece (Lorenz Moosmann).

5.3.3 Large scale topographic and climatic regions

The large-scale topographic situation – plain, medium mountains, high mountains exposed to oceanic climate or shaded from it – is a key factor for the regional and local meteorological conditions, influencing both dispersion situation and regional and long-range transport.

No quantitative criteria for separating Europe into dispersion-relevant topographic regions can be derived. Large topographic units with homogeneous terrain are proposed; these are given for central Europe in Figure 25 and listed below.

1. Alps north or west of the main chain, exposed to oceanic air masses
2. Alps south or east of the main chain, shaded from oceanic air masses
3. the Po Valley
4. the Appenines
5. the western Mediterranean Coast
6. the Rhone-Saone Valley
7. the northern pre-alpine lowlands(Alpenvorland, Schweizer Mitteland)
8. Lower mountain ranges north of the Alps: Jura, Vosges, Schwarzwald (Black Forest), Schwäbische Alb (Swabian mountains)
9. the western European Lowlands (France to northern Germany, including Belgium and Netherlands)
10. the Upper Rhine Valley (Oberrheingraben)
11. Deutsches Mittelgebirge (Central German Uplands)
12. Bohemian Massif (Böhmerwald, Erzgebirge, Sudeten, Böhmisch-Mährische Schwelle, Mühl- and Waldviertel)
13. the north-eastern Austrian lowlands and Moravia
14. the Pannonian Plain
15. the south-easten pre-alpine lowlands(Austria, Slovenia, Croatia)
16. the Dinaric Alps
17. the eastern Adriatic coast
18. the Carpathians
19. Transylvania
20. Walachia
21. the northern Central European Lowlands (Germany, Poland)
22. the central Bohemian basin.

Boundaries between these regions are clear where there is a separation of mountainous areas from lowlands. Delimitation of flat or hilly areas is, however, not unambiguous, and „representative areas” need not be delimited at boundaries of such regions.

Further it should be noted that a partition of very large uniform areas, for example the plains along the Atlantic coast in western and northern central Europe, is not possible on the basis of objective criteria.

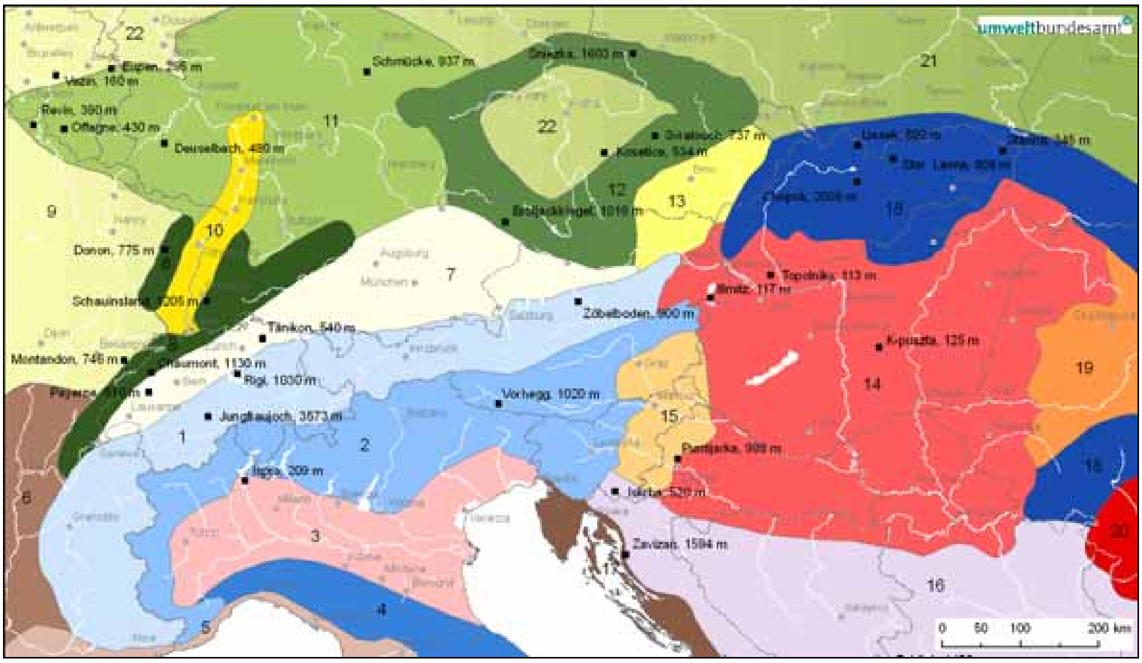

Figure 25: Proposed delimitation of large-scale topographic/climatic regions in central Europe (incl. EMEP sites).

In addition to the large-scale topographic regions, a criterion for maximum distance/extension of the area of representativeness (chapter 5.4) can be applied.

5.4 Maximum distance related to atmospheric transport and conversion

The validation of the method for assessing the representativeness of Austrian monitoring stations in chapter 7.2.2 compares the results obtained by using the large-scale topographic region with those obtained using the application of a maximum distance related to atmospheric transport and conversion – for which in eastern central Europe a distance of approximately 100 km is proposed.

Chapter 7.2.2 suggests that in most cases a radius of 100 km gives somehow more reasonable results, because the large-scale topographic regions may cover very large regions extending over several 100 km. E.g. the Northern Alps extend from south-eastern France to Wien (Vienna), and it might be questionable if a monitoring site in the Wienerwald (Vienna Woods) is representative of the Provence (Southern France), even in the same local and regional dispersion situation and with the same local emissions.

A stringent application of the criteria for the regional dispersion situation can supply the appropriate information of the topographic structure and thereby separate lowlands, mountainous terrain or coastal areas, which are key features of the large-scale topographic region.

The maximum extension of the representative area is based on considerations regarding the chemical transformation of pollutants during atmospheric transport. Processes of interest are the **conversion of NO_2 to other oxidised nitrogen compounds**, the **formation of ozone in urban (or industrial) plumes** and the **formation of secondary particles**. The chemical processes leading to the conversion of NO_2 and the formation of nitrate cover a time scale of **approximately 12 hours**; ozone formation is an even faster process.

Based on a time scale of 12 hours, the **average transport distance over this time is considered the maximum extension of the representative area**. This transport distance, of course, depends on the wind speed and therefore shows large temporal variations, as well as regional differences. Longer transport distances characterise oceanic climate, whereas average transport velocities in southern and eastern Europe are lower.

Based on backward trajectory calculations for the region of Wien, average transport distances of about 100 km are proposed as the maximum distance for representativeness within central Europe.

Nevertheless, this „distance" is not equal for all directions; it is longer to the west due to higher wind speeds from this direction, about 100 km for winds from north and south and less for easterly winds.

It can be assumed that the transport distance over 12 h is generally **longer under oceanic climate conditions** (i.e. in northern and western Europe) and **shorter under Mediterranean und continental climate** conditions.

As an example, Figure 26 shows the average transport distance (2000-2005) for air masses reaching Illmitz, derived from ECMWF backward trajectories (3-dimensional trajectories, reaching Illmitz 100 m above ground).

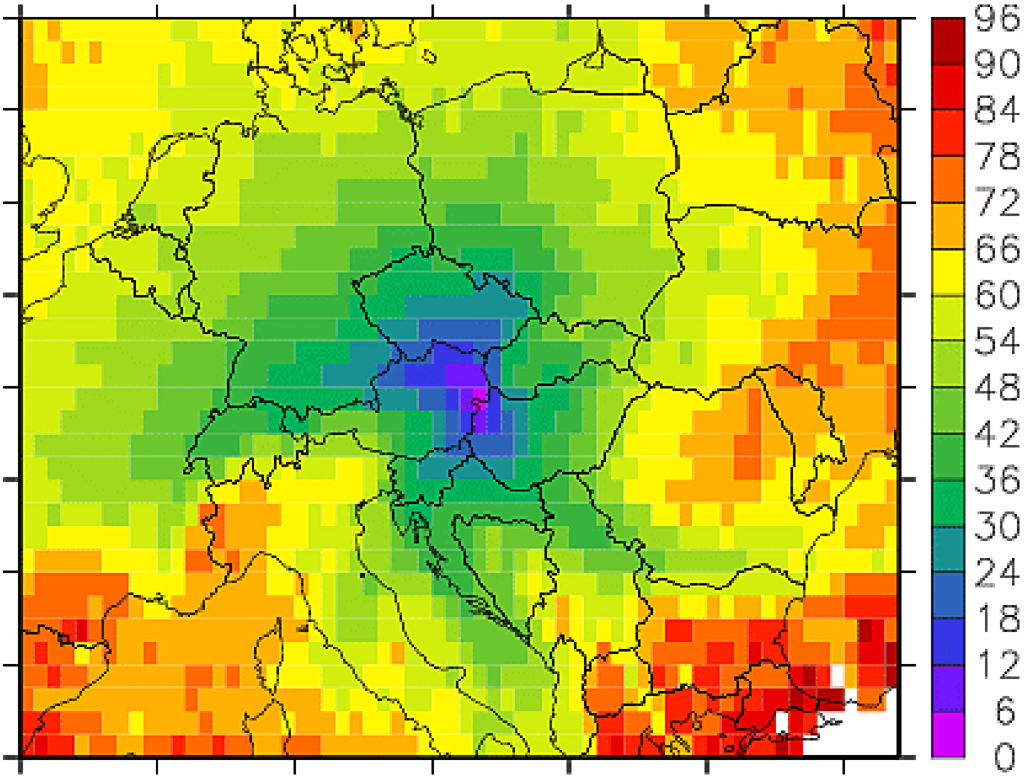

Figure 26: Average transport time (hours) for air masses reaching the EMEP site Illmitz (eastern Austria).

5.5 Regional background concentration

The regional background concentration, which represents a scale of approx. 100 km, has been discussed as an input for the criteria for assessment of the area of representativeness.

The regional background concentration can be identified by

- measurement or
- modelling.

Determining the regional background concentration by measurement poses the problem of appropriate monitoring sites and their representative area having to be identified in advance.

Regional background concentrations retrieved from EMEP model are of good quality for NO_2 (Figure 27), but PM10 concentrations are largely underestimated (in Austria by approximately 50 %).

Rural background NO_2 concentrations from the EMEP model could in principle be used as input, but the background NO_2 concentrations are quite low and spatially uniform. For example, a background concentration of 10 µg/m³ would – according to the criteria given in Table 20 within a concentration range of ±5 µg/m³ – be representative of a very large area covering most of central Europe.

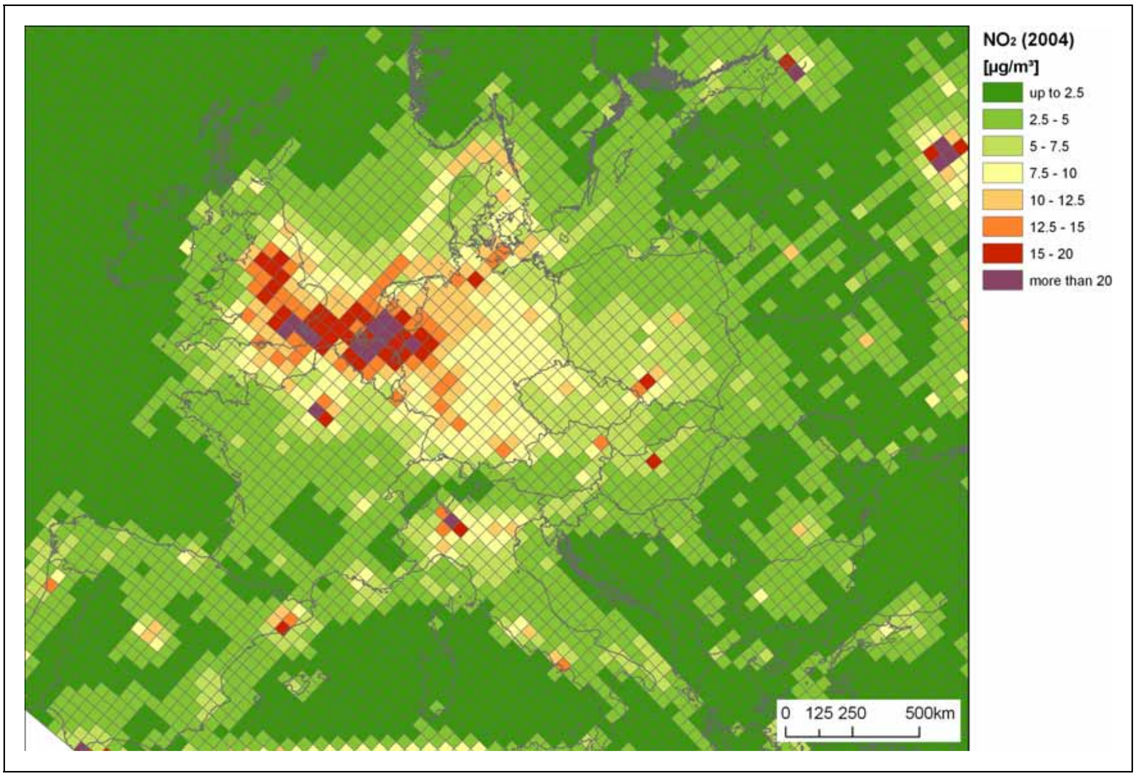

Figure 27: NO_2 concentrations from EMEP model, 2004.

Based on the above mentioned limitations of the information about the regional background concentration, the present study proposes that it should not be used as a criterion for representativeness, and that the large-scale topographic regions (chapter 5.3.3) and a maximum distance (chapter 5.4) should be applied for the large-scale delimitation of the area of representativeness.

5.6 Recommended procedure for the delimitation of the representativeness areas

This chapter gives practical advice on how to proceed with the operational delimitation of the area of representativeness of a certain monitoring station. Two situations are dealt with separately:

1. Model data are available on the appropriate spatial scale
2. The concentration distribution has to be assessed by surrogate information – which can also be used to parameterise the emission class.

The validation (chapter 7) focuses more on the use of surrogate data because this is more difficult (and also less precise) than the use of model data. Nevertheless it has to be kept in mind that model results do not necessarily reproduce measured data with satisfying accuracy. If large deviations between modelled and measured concentrations are known – e.g. in the case of PM – such differences have to be taken into account.

Information about the dispersion situation is assumed to be obtained in a similar way for both situations.

Regarding emissions, availability of a complete emission inventory is the optimum case; otherwise, emissions have to be assed using surrogate information.

5.6.1 Delimitation based on model data

If model data are available, the concentration criteria given in chapter 4.2 are applied to the modelled concentration field, thus defining a certain area within a given concentration range around the measured concentrations. These criteria are checked, as proposed, over a period of three years (if available).

When using modelled data, the model resolution is related to the type of those monitoring sites whose representativeness is to be determined:

- the representativeness of traffic related monitoring stations requires models which show streets, i.e. a model grid of about 10 m;
- the representativeness of urban background monitoring stations requires a model resolution of some 100 m;
- models with a resolution of about 1 km or more can be used to assess the representativeness of rural background sites.

The area which fulfils the concentration criterion has to be superimposed on the areas which fulfil the criteria for the emission class and the local and regional environment.

The large-scale delimitation is based upon the large-scale topographic regions (chapter 5.3.3) and a maximum distance related to atmospheric transport and conversion (chapter 5.4).

Validation cases using modelled data are presented in chapter 7.2.8, 7.3 and 7.4.

5.6.2 Assessment of concentrations based on surrogate data

Different methods have been developed to assess the spatial concentration pattern using surrogate data, covering different levels of sophistication from simply using land-use information to simple modelling techniques (see chapter 5.1.2).

Such simple assessment methods can also be used to estimate emissions.

The proposed delimitation of representativeness areas for north-eastern monitoring stations in chapter 7.2.2 uses a simple empirical relation between measured concentrations and basic geographical information:

- CORINE Landcover
- TeleAtlas functional road classes
- Population per municipality

to estimate both concentrations and emissions.

This simple method, however, can only be applied for rural and small-town locations, with only a coarse representation of traffic influence. For urban areas, much more precise information about both emissions and concentration patterns is essential.

5.6.3 Assessment of emission class using surrogate data

A test of the classification method suggests that TeleAtlas roads are a simple surrogate for road traffic emissions (see chapter 6.5.11). The vicinity of roads of classes up to FRC 3 or 4 is estimated to be classified as „medium" and „high" regarding local road traffic.

The relation between functional road class (FRC) and emissions – or nearby measured NO_x concentrations – is not significant. Especially in urban areas, the FRC is not a good approximation for local traffic emissions.

CORINE Landcover areas 1.1.1 (continous urban fabric) and 1.1.2 (discontinuous urban fabric) can be used as a surrogate for high and medium domestic heating emissions. However, with respect to the large spatial variability of PM10 emissions per capita, more precise data of domestic heating emissions are essential for a fairly accurate assessment of representativeness. However, areas outside the CLC classes 1.1.1 and 1.1.2 can be classified easily as „low emissions" regarding domestic heating.

CLC areas 1.2.1. (industrial and commercial units), 1.2.3 (port areas), 1.2.4 (airports) and 1.3.3 (contruction sites) can be used as a surrogate for industrial emissions. But keeping the difficulties of assessing the impact of industrial emissions in mind (see chapter 2.2.1.3), the CLC areas are only a very rough approximation.

5.6.4 Assessment of the dispersion situation

The local environment in urban areas has to be thoroughly assessed using either quantitative information on street geometry and building structure (for example Wien, „multi-purpose map") or a detailed qualitative assessment of certain streets. CLC classes 1.1.1 and 1.1.2 can be used as a very simple surrogate for building structure.

The regional dispersion situation should be assessed using topographic information.

Regarding ozone (chapter 2.5.2), an assessment of the classification is recommended using expert knowledge. No quantitative criteria can be given.

The regional ozone formation potential may be assessed using the frequency of information threshold exceedances.

5.7 Statistics of whole time series

5.7.1 Correlation coefficient, coefficient of divergence and mean square difference

A completely different approach to assess „similarity” represents statistical relations of time series, which do not only deal with absolute differences of annual parameters, but also implicitly consider the temporal variation on a shorter time scale. Therefore, such statistical relations are able to represent the spatial variation of air pollutant concentrations due to those external parameters – like emissions and the dispersion situation due to buildings, topography and climate – which are set as the 2nd criterion for the definition of representativeness.

Such parameters provide a statistical measure of the differences in the individual simultaneous concentrations of the time series (i.e. *statistics of the differences* in simultaneous values), and represent a different and independent approach compared to the definition of representativeness (chapter 4), which is based upon *differences in the statistics* of simultaneous values).

Statistical parameters of differences in simultaneous values are compared with the results of the method to assess the representative area derived from the definition developed in this study (chapter 7.6).

The present study does not further pursue this approach and gives no recommendations on its application, but a short description of its results in comparison with the method proposed in chapter 5.6 is given in chapter 7.6.

The following parameters are often used in statistical evaluations and can be regarded as reasonable options:

The **correlation coefficient** characterises the similarity of the temporal variation of two time series, irrespective of the absolute level. It is close to 1 for parallel time series, close to 0 for time series with no relation and close to -1 for contrary time series.

The **coefficient of divergence** (COD) is the square root of the sum of the squared differences of the simultaneous values at two monitoring sites divided by the squared sum of these values. It takes account of the absolute concentration difference between two monitoring sites. It is low (close to zero) for „similar” time series and close to 1 for strongly differing time series. Since the sum of the concentrations is put in the denominator, pairs of highly polluted sites result in very low CODs.

In addition the root of the **mean square difference** (MSD), which is in fact the numerator of the COD, represents the difference between simultaneous values at two sites (the square is calculated to gain only positive values, the root for re-gaining numerical values in the measurement unit). The root MSD is low (close to zero) for „similar” time series and high for strongly different time series; there is no upper boundary, and the range of values depends on the variation of the concentration values. Since the root MSD has the same unit as the measured concentrations, it is quite an illustrative parameter for the „differences” of time series.

A test of these statistical parameters for Austrian data sets of NO_2, PM10 and ozone suggests that the root MSD should be used as a measure for „similarity”. The major disadvantage of the correlation coefficient is that it does not take into account absolute concentration values, which makes it not sufficient to fulfil the requirement of similar annual mean values or percentiles. The major disadvantage of the COD is that pairs of highly polluted locations (since the sum of the concentrations is put in the denominator) are calculated to be „very similar”, despite the fact that their average concentrations differ distinctively more than those of pairs of lowly polluted locations. The root MSD has turned out as the best proxy for the difference between average concentrations or annual percentiles.

A definition of representativeness based on the mean square difference may be formulated as follows:

A monitoring station is representative of a location if the *root mean square difference between the simultaneous short-term concentrations* at the station and at the location is less than a certain threshold value.

The threshold value and the short-term concentrations for calculating MSD (daily averages, hourly averages etc.) have to be defined for each pollutant.

The main advantage of this definition is that it takes into account the temporal variation of concentrations. If stations show similar average concentrations but differences in the temporal variation, these differences are still visible in the root mean square difference.

In the vicinity of certain industrial plants, stations with similar characteristics but differences in concentrations on certain days – because the source direction is different – may show large mean square differences, suggesting a small representative area. However, this possible drawback of using the mean square difference has not been found in Austria.

For these statistical parameters, spatial similarity was tested on Austrian air quality data (see chapter 4 of the interim progress report).

The root mean square difference can be used as a proxy for the two criteria for the definition presented in chapter 4.2, since it covers both the similarity of the absolute concentration (related to the annual mean or an annual percentile) and the influence of common reasons. Common external factors – emissions, dispersion situation, and regional background concentration – lead to a similar temporal variation of the measurement values and therefore to low MSDs. Emissions from different types of sources show characteristic temporal variations, and thus the similarity of measurement time series characterises the influence from the same emissions.

Meteorological conditions show similar temporal characteristics in geographical vicinity, and thus restrict the area of representativeness to geographical regions of a limited extent. Also the dispersion situation imposed by the topographic structure leads to geographically limited areas of representativeness.

In the same way, similar regional background concentrations impose a spatial structure on the statistical parameter used for the assessment of representativeness.

Chapter 7.6 discusses the root of the mean square difference of NO_2, PM10 and Ozone time series for selected sites – also presented in the validation chapter 7.2 – in Austria.

5.7.2 Conclusions

The definition for representativeness given in chapter 4.3 is based both on a concentration criterion, related to annual values (average or percentile values) and on „similar causes for similar concentrations". The second criterion shall ensure that similar concentrations are not put in the same representative area by chance, because similar annual averages or percentiles can be caused by a combination of quite different external influencing factors like emissions, dispersion situation, transport and chemical transformation.

Statistical parameters of time series, as discussed in chapter 5.7.1, consider the temporal variability of the concentration and therefore implicitly take into account external parameters like emissions and any type of atmospheric processes. The absolute concentration level and the temporal variability are reflected in the above discussed parameters to a different extent; the correlation coefficient does not at all consider the absolute concentration, whereas the COD tends to give „high similarity" rather for pairs of highly polluted sites, and the RMSD tends to give „high similarity" rather for pairs of lowly polluted sites.

These statistical parameters could therefore be used as a surrogate for external parameters (emissions, atmospheric processes). Analyses of Austrian data suggest that the RMSD is the best approximation to the criteria mentioned in chapter 4.3, but gives, anyhow, partly different results (see chapter 7.6).

As the best surrogate for the criterion for emissions and dispersion situation – in addition to the assessment of absolute concentration values according to Table 20 – the correlation coefficient is recommended. The correlation coefficient is quite sensitive to

- the spatial distance/vicinity of monitoring stations
- the topographic situation, insofar as it influences the daily variation of concentrations and the contribution/absence of regional and long-range transport
- emissions, mainly separating traffic-influenced sites from background sites.

6 TEST OF THE CLASSIFICATION METHOD

6.1 Introduction

Chapters 6 and 7 describe the testing and validation procedure, which constitutes Task 3 of the overall project. The objective of this task is to check if the proposed methods are fully applicable to European data-sets and how well they perform.

There is an important difference between the validation of methods for representativeness and methods for classification. A classification method defines only groups of monitoring stations with similar properties and does not imply similar values for other properties; hence there is no value to be tested and validation is restricted to practicability testing.

A representativeness method predicts – with significant uncertainty, particularly when performed on the basis of surrogate data – if concentrations at two locations are similar or not, and hence such a method can be quantitatively tested and validated.

The following basic questions will be addressed when testing the classification method:

- Comparison of different classification parameters for local road traffic with measured concentrations of NO_x;
- Selection of class boundaries – aussuming three classes for each type of emission in a first approach;
- Comparison of class average concentrations with measured pollution levels;
- Comparison of the classification results with the (official) EoI classification (Traffic, industrial, background);
- Comparison of the classification results between NO_2 and PM10 – is a harmonisation possible?

Different input parameters for different levels of sophistication are compared and recommendations for requirements of the quality of input data are given.

6.2 Data used

6.2.1 Data sources (EEA/EU Member States)

The original idea for testing the method for classification and assessment of representativeness was to use data from regions with different climatic conditions (e.g. maritime, continental, mediterranean climate) and different topographic conditions (e.g. flat area, Alpine regions). Nevertheless, it soon turned out that the easy and timely availability of all relevant input data – measurement data, emissions, topographic information, model data – was a more stringent criterion. Therefore, data from the following regions were used:

- **Austria**: A large number of monitoring data, model results, emission inventories for some cities and provinces, and surrogate data (traffic volume, industrial emissions, population densities etc.) are readily available. Data from Austria is used especially to check the methods for their applicability to complex topography.
- **Netherlands, Rijnmond Region**: A large number of monitoring stations, emissions and model data with high resolution are available. This region of the Netherlands is characterised by completely flat terrain (which imposes no spatial structure on concentrations) in oceanic climate (favourable dispersion situation).

6.2.2 Pollutants

Areas with similar characteristics are determined according to the proposed method for the following pollutants: NO_2, O_3 and PM10. For a limited number of stations, such areas are determined for NO_x and PM2.5.

6.3 Class boundaries

As a first step, three classes are proposed for each of the three emission categories.

The selection of class boundaries to separate these classes is in any case somehow deliberate. It was attempted to derive class boundaries from the frequency distribution of the classification parameter for the emission categories „local road traffic" and „domestic heating" for all Austrian monitoring stations; including the Dutch (Rijnmond) monitoring stations does not change the picture. Class boundaries were selected as numerical values of the classification parameter where the frequency distribution shows some bends. The distribution of the road traffic emission parameter suggests quite clear class boundaries, but the distribution of the domestic heating emissions, especially for PM10, is not unequivocal and may invite discussion.

Even the class boundary selection for road traffic emissions is somehow deliberate and should be further discussed using data from other European countries.

The class boundaries were derived from the classification parameters of the „level 2 approach" (chapter 6.5.4 and 6.5.5), which is based on more accurate data than the „level 1 approach", whereas „level 3 data" are not available throughout Austria.

6.4 Procedure for testing the classification method

A detailed test of the **classification system** is performed for the regions listed in chapter 6.2. In addition, the classification is applied to a larger number of stations from the Austrian network and other regions mentioned in chapter 6.2, for which the required meta-data (see chapter 2) are available.

These stations are classified according to the proposed method, and the following questions are addressed:

- Which class boundaries are appropriate?
- What is the proportion of stations in the different classes (i.e. are the stations spread across all classes or only a few classes)?
- How does the classification relate to measured pollution levels?
- As a second step, different types of input data – with different levels of sophistication – are compared, and the resulting differences in the classification results are presented and discussed.

The tests of the classification require appropriate basic data on emissions or surrogate information on emissions.

6.5 Test of the classification method using Austrian data

The classification approaches with different levels of detail (as introduced in chapter 2) are compared for NO_x and PM10 – see Table 29.

Table 29: Input data for classification of Austrian AQ monitoring stations.

Emission category	Level	Input
Road traffic, NO_x and PM10	Level 1	Traffic volume, uniform emission factor for all streets, specific to heavy duty vehicles and passenger cars
Domestic heating, NO_x and PM10	Level 1	Population, uniform emission factor
Road traffic, NO_x and PM10	Level 2	Traffic volume, emission factor for different types of streets, specific to heavy duty vehicles and passenger cars
Domestic heating, NO_x and PM10	Level 2	Population, specific emission factors for different types of regions: urban, suburban, rural

The population distribution is derived from gridded data on 2.5 km resolution.

The contribution of industrial emissions is estimated by expert judgement, which is based on experience with several studies on air quality issues (OÖ LANDESREGIERUNG 2003, STMK LANDESREGIERUNG 2003, STMK LANDESREGIERUNG 2006, UMWELTBUNDESAMT 2003, UMWELTBUNDESAMT 2003a UMWELTBUNDESAMT 2004, 2004a, 2005, 2005a, 2005b, 2005c, 2006, 2006b).

Chapter 6.5.1 compares the traffic emission parameter (as defined in chapter 3.2.3) for each monitoring site with the measured NO_x and NO concentrations; calculations of the traffic emission parameter with the distance and the square root of the distance in the denominator are discussed – and the calculation with the square root of the distance is definitely justified.

A similar test of domestic heating emissions is not possible, since there is no pollutant whose concentration is predominantly caused by domestic heating (as NO and NO_x originate from road traffic).

In chapters 6.5.2 to 6.5.5 the classification results for NO_x and PM10 monitoring stations with a level 1 and a level 2 approach are presented. Since level 2 is based on more refined data, the class boundaries which are suggested by level 2 are also applied to level 1 data. The classification itself – i.e. the distribution of the monitoring sites among each of the three classes – is compared between the two levels in chapter 6.5.7.

Chapter 6.5.8 presents a comparison with level 2 results for selected areas for which emission inventory data are available.

6.5.1 Test of the traffic emission parameter

This chapter deals with

- the relation between the traffic emission parameter (chapter 3.2.3) and measured NO, NO_2 and NO_x concentrations for Austrian AQ monitoring stations;
- the comparison of the traffic emission parameter with different distance functions: the reciprocal square root of the distance (as in the definition in chapter 3.2.3) and the distance itself.

The relation between the classification parameter (NO_x emission/square root of distance) on level 2 (related to Table 14) and the annual mean concentrations of NO, NO_2 and NO_x (µg NO_2/m³) for the year 2005 is depicted in Figure 28. Figure 29 gives the same relation for the traffic emission parameter using the distance itself in the denominator (instead of the square root of the distance).

The coefficient of determination (R²) for annual average concentrations obtained with the **square root of the distance** (Figure 28) is 0.79 for NO_x and 0.81 for NO; with the **distance** itself (Figure 29), it is 0.56 for NO_x and 0.62 for NO. With the level 1 input data, very similar coefficients of determination are obtained.

Along with the simple model simulations (see chapter 3.2.3.1), this allows for the strong recommendation that the square root of the distance should be used to parameterise the distance between road and monitoring station.

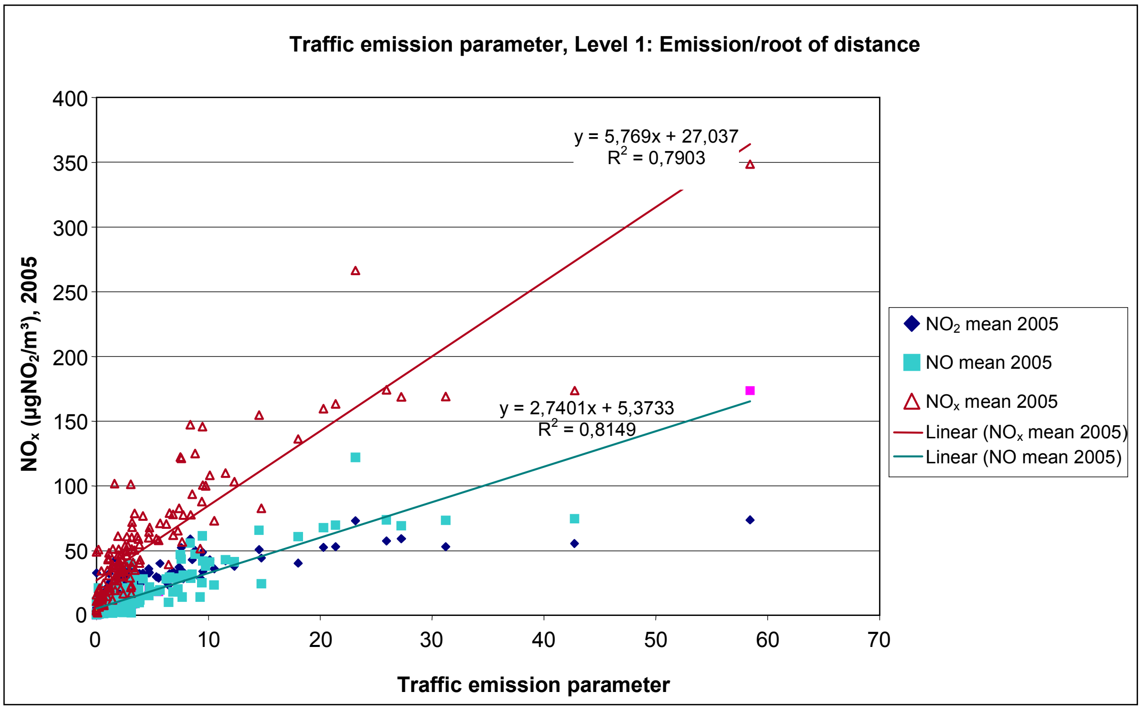

Figure 28: Relation of the „traffic emission parameter" (NO_x emission/√distance) to the average NO and NO_x concentrations for Austrian NO_x monitoring stations.

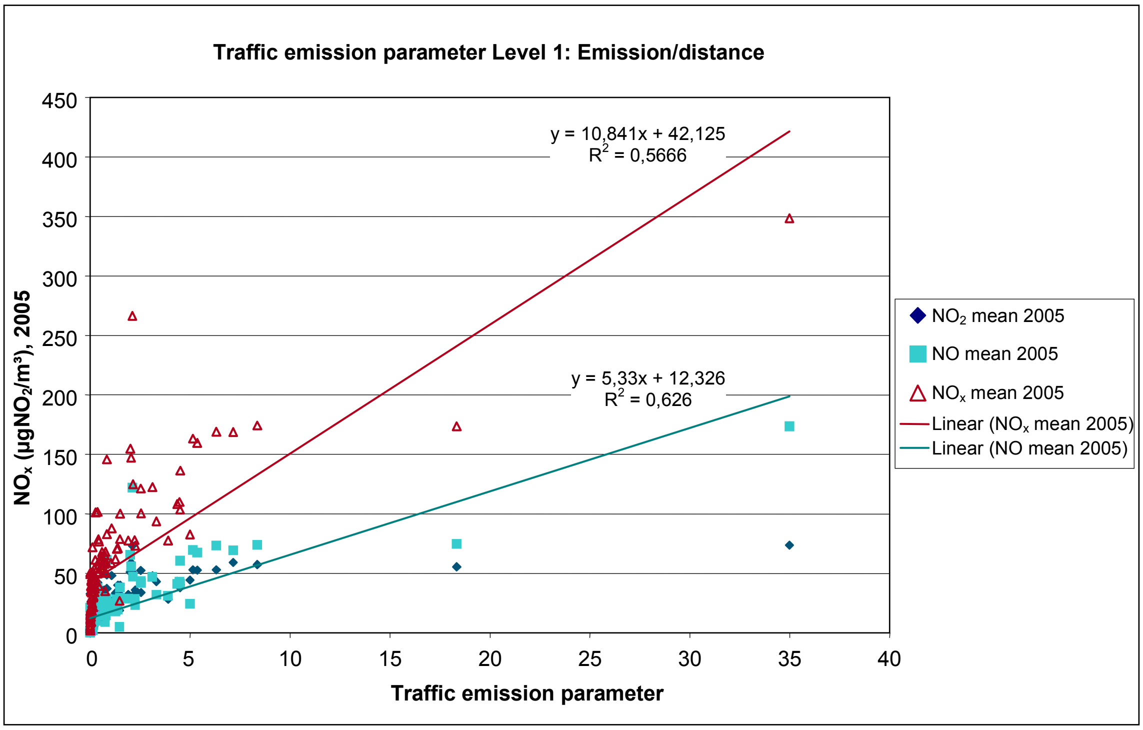

Figure 29: Relation of an alternative „traffic emission parameter" (NO_x emission/distance) to the average NO and NO_x concentrations for Austrian NO_x monitoring stations. The two monitoring sites with the highest traffic emission parameters are Enns A1 and Vomp A12 (motorway stations).

Even if the two monitoring stations with the highest traffic emission parameter (Enns A1 and Vomp A12 in the immediate vicinity of motorways – high traffic emissions at low distance, which form the „outliers" especially in Figure 29) are excluded, the parameter obtained with the square root of the distance shows higher coefficients of determination (0.77 for NO and NO_x) compared to the parameter with the distance in the denominator (0.60 for NO and NO_x).

The scattered distribution of the concentration values can mainly be attributed to different dispersion situations (due to differences in topographic locations). For example, the two stations with the highest NO_x concentrations are Vomp A12, located at a motorway in an Alpine valley, and Wien Hietzinger Kai, located at a busy urban street near buildings. Both locations are – in a different way – subject to adverse dispersion situations. By contrast, the monitoring site with the second highest classification parameter is Enns A1, located at a motorway in a rural environment, on flat terrain and with free air flows in the surroundings.

6.5.2 Classification of NO_x monitoring stations on „level 1"

The test of the classification of all Austrian AQ monitoring sites for NO_2/NO_x was based on a level 1 approach for the whole of Austria, using the input data (activity data) and emission factors listed in Table 30. The average emission factors (kg/km per vehicle) of road traffic for Austria are calculated as the total national emissions divided by the total traffic volume (vehicle-km). Similarly, the per capita emission of domestic heating is calculated as the total national emissions divided by the total population.

Table 30: Input data and emission factors for road traffic and domestic heating emissions in Austria, level 1, NO_x.

	Activity data	**Emission factor**
Local road traffic, passenger cars	Traffic census for the streets in the vicinity, partly estimated or extrapolated from other locations	0.48 g/km
Local road traffic, heavy duty vehicles		8.85 g/km
Domestic heating	Population within 1 km radius	1.6 kg/person.year

Industrial sources: expert estimation (from emission data and studies on air quality) of the contribution to measured pollution level.

6.5.2.1 Distribution of the road traffic emission parameter, level 1

The distribution of the road traffic emission parameter for NO_x, calculated at level 1 (see Table 14) is depicted in Figure 30.

For classification, the class boundaries derived from the distribution of the traffic emission parameter at level 2 (see chapter 6.5.4) – 5 g/($m^{3/2\cdot}$day) and 15 g/($m^{3/2\cdot}$day) – are applied.

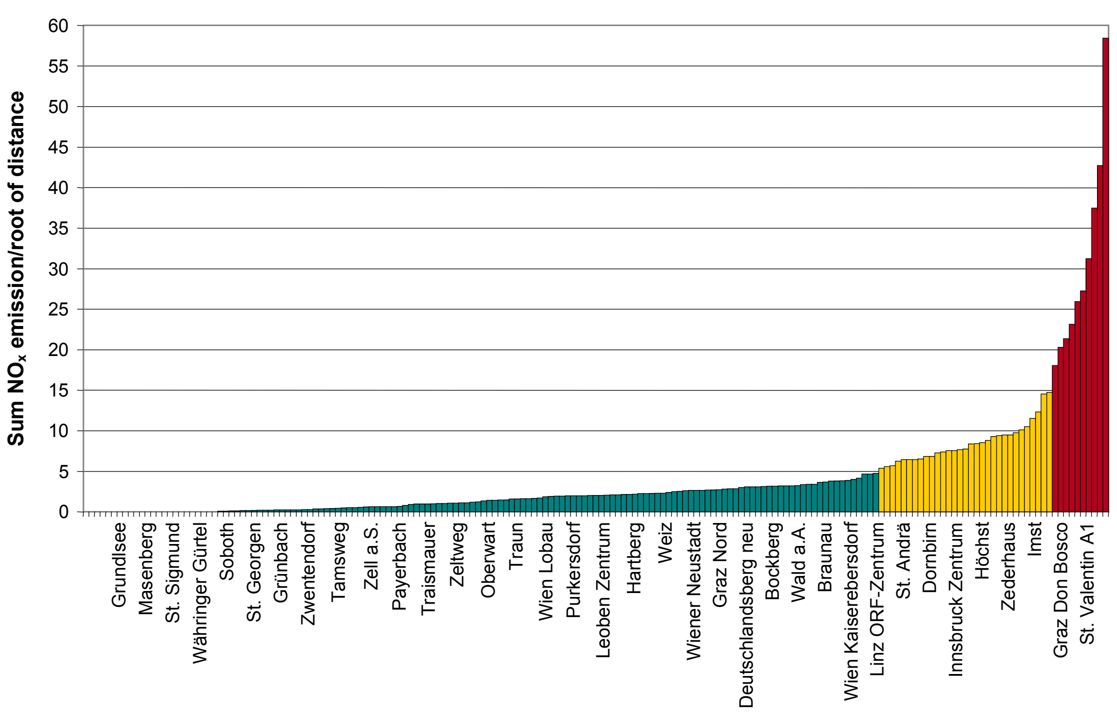

Figure 30: Distribution of the road traffic emission parameter for Austrian monitoring stations, NO_x, level 1 (g/($m^{3/2\cdot}$day)).

6.5.2.2 Distribution of the domestic heating emissions, level 1

The distribution of the domestic heating emissions of NO_x in the surroundings within a 1 km radius is depicted in Figure 31 (level 1, derived from population density).

The level 2 approach (chapter 6.5.4, Figure 35) suggests class boundaries at 9 and 20 t/year. These class boundaries are also used in Figure 31. However, it has to be stated that the level 2 approach with regionally specific emissions gives a totally different picture.

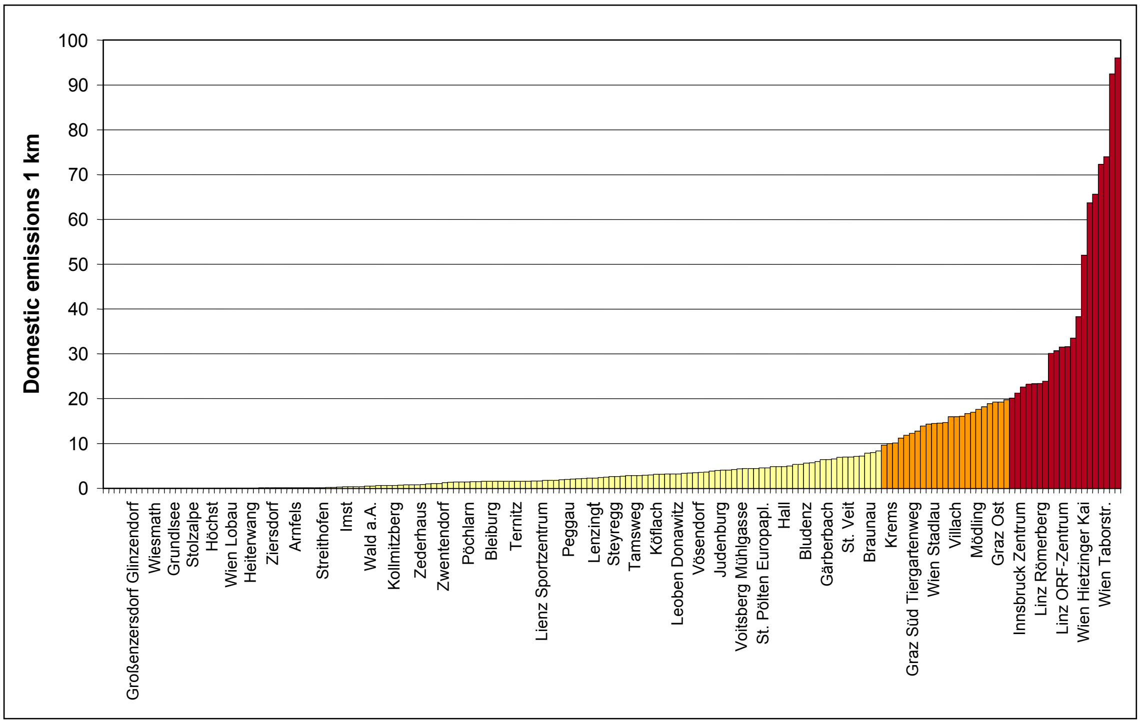

Figure 31: Distribution of the domestic heating emissions for Austrian monitoring sites, level 1 (uniform emission factor for NO_x), t/year.

6.5.2.3 Classification results

Table 31 lists the number of monitoring stations for each of the three classes traffic, domestic heating and industrial emissions, and the average NO_2 concentrations for each class for 2003 and 2004 in µg/m³. Table 32 gives a cross-classification according to traffic, domestic heating and industrial emissions of NO_x.

Table 31: Classification results for Austrian NO_2 monitoring sites, level 1, separate entries for traffic, domestic heating and industrial emissions. Number of stations per class, average concentration per class for 2003 and 2004.

	Class „low"			**Class „medium"**			**Class „high"**		
	Number	**NO_2 (µg/m³)**		**Number**	**NO_2 (µg/m³)**		**Number**	**NO_2 (µg/m³)**	
		2003	2004		2003	2004		2003	2004
Traffic	**98**	26	26	**28**	39	37	10	54	55
Domestic heating	**85**	30	30	**32**	39	39	19	44	42
Industrial	**127**	38	36	**9**	34	34	0		

Table 32: Cross-classification according to traffic, domestic heating and industrial emissions of NO_x, level 1. Number of stations and average NO_2 values 2004, µg/m³.

		Traffic low		**Traffic medium**		**Traffic high**	
		Number	**NO_2 (µg/m³)**	**Number**	**NO_2 (µg/m³)**	**Number**	**NO_2 (µg/m³)**
Domestic H low	Industrial low	67	15	10	34	5	49
	Industrial medium	3	22	0		0	
Domestic H medium	Industrial low	15	26	9	36	3	48
	Industrial medium	2	32	2	39	1	53
Domestic H high	Industrial low	10	29	7	41	1	68
	Industrial medium	1	31	0		0	

The classification according to local road traffic and domestic heating emissions (Table 31) is clearly related to the average NO_2 concentrations.

No clear relation between NO_2 concentrations and the classification of industrial emissions can be seen. The – comparably low – influence of industrial emissions is obviously superseded by other sources, especially road traffic.

„Mismatches" between the classification and the concentration may in any case result from the following reasons:

- different dispersion situations (may influence averages for small classes);
- insufficient relation between real domestic heating emissions and population distribution (on which the classification is based);
- insufficient assessment of industrial contribution.

6.5.3 Classification of PM10 monitoring stations on „level 1"

The test of the classification of all Austrian AQ monitoring sites for PM10 was based on a level 1 approach for the whole of Austria, using the input data (activity data) and average emission factors listed in Table 33. The average emission factors (kg/km per vehicle) of road traffic for Austria are calculated as the total national emissions divided by the total traffic volume (vehicle-km). Similarly, the per capita emission of domestic heating is calculated as the total national emissions divided by the total population.

Table 33: Input data and emission factors for road traffic and domestic heating, PM10.

	Activity data	**Emission factor**
Local road traffic, passenger cars	Traffic census for the streets in the vicinity, partly estimated or extrapolated from other locations	0.08 kg/km.year
Local road traffic, heavy duty vehicles		0.40 kg/km.year
Domestic heating	Population within 1 km radius	0.8 kg/person.year

Industrial sources: expert estimation (from emission data and studies on air quality) of the contribution to measured pollution level.

6.5.3.1 Distribution of the traffic emission parameter

The distribution of the classification parameter is depicted in Figure 32. The proposed class boundaries of 0.4 g/($m^{3/2}$·day) and 1.1 g/($m^{3/2}$·day) are derived from the level 2 approach (chapter 6.5.5, Figure 36).

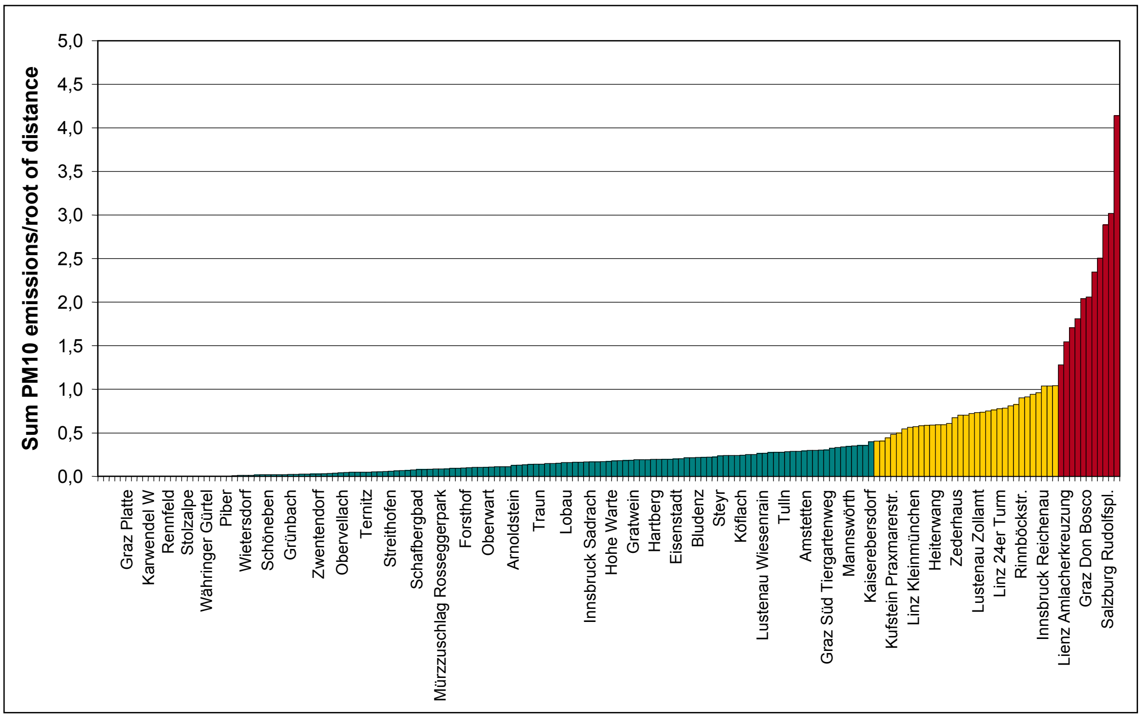

Figure 32: Distribution of the road traffic emission parameter for Austrian monitoring stations, PM10, level 1 (g/($m^{3/2}$·day)

6.5.3.2 Distribution of the domestic heating emissions

The distribution of the domestic heating emissions of PM10 in the surroundings within 1 km is shown in Figure 33. The class boundaries are derived from the level 2 approach (chapter 6.5.5, Figure 37) as 1 and 3 t/year.

The distribution of the level-2-emissions from domestic heating (Figure 37) however differs largely from level 1 – with maximum domestic heating emissions less than 8 t/year. The differences between level 1 and level 2 are much higher for PM10 compared to NO_x, due to the differences in emission factors in urban and rural areas (more wood burning in rural areas with high PM10 emissions). In the level 2 approach, much lower domestic heating emissions are attributed to large cities with high population densities, and therefore the maximum emissions in the level 2 approach are much lower than for level 1. On the other hand, small towns and rural settlements have much higher domestic heating emissions compared to level 1.

However, the distribution of the domestic heating emissions at level 2 (Figure 37) do not really suggest clear boundaries; boundaries at about 2 and slightly below 4 t/year would also look reasonable.

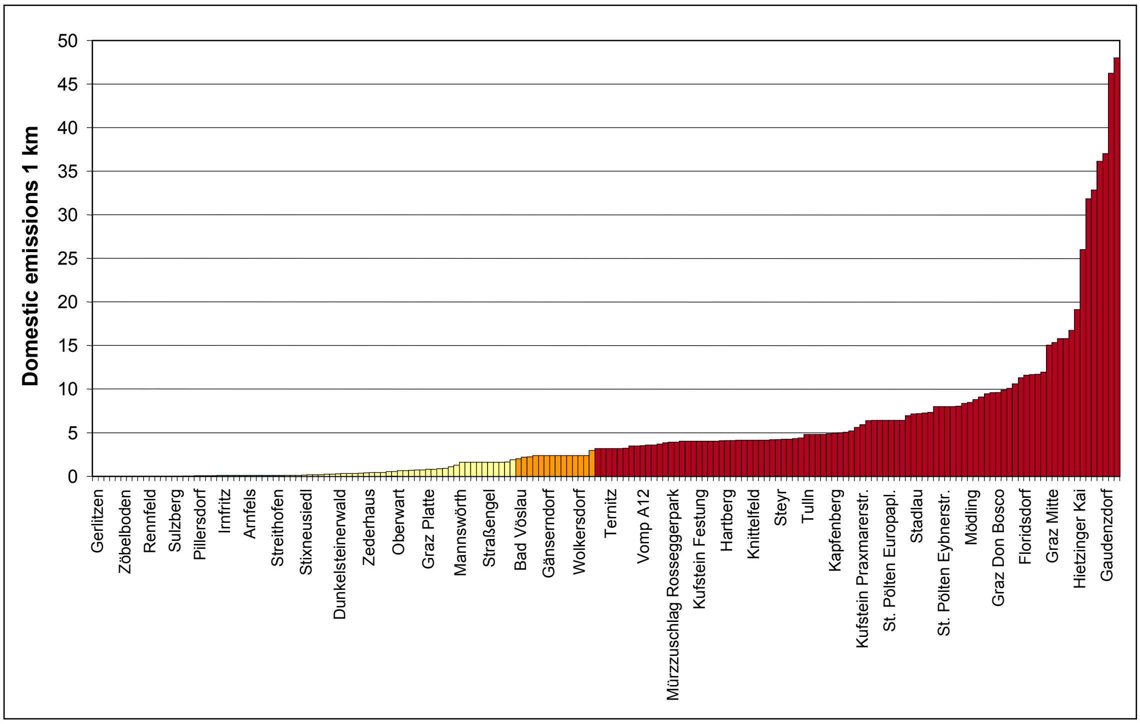

Figure 33: Distribution of PM10 domestic heating emissions, level 1 (t/year).

6.5.3.3 Classification results

Table 34 lists the number of monitoring stations for each of the three classes of traffic, domestic heating and industrial emissions, and the average PM10 concentrations for each class for 2003 and 2004 in µg/m^3.

Table 35 gives a cross-classification according to traffic, domestic heating and industrial emissions of PM10.

Table 34: Classification results for Austrian PM10 monitoring sites, separate entries for traffic, domestic heating and industrial emissions, level 1. Number of stations per class, average concentration per class for 2003 and 2004.

	Class „low"			**Class „medium"**			**Class „high"**		
	Number	**PM10 (µg/m^3)**		**Number**	**PM10 (µg/m^3)**		**Number**	**PM10 (µg/m^3)**	
		2003	2004		2003	2004		2003	2004
Traffic	63	30	25	28	32	29	8	32	27
Domestic H.	20	25	20	15	30	28	64	36	31
Industrial	84	28	25	13	35	31	2	38	31

Table 35: Cross-classification according to traffic, domestic heating and industrial emissions of PM10, level 1. Number of stations and average PM10 values 2004, µg/m³.

		Traffic low		**Traffic medium**		**Traffic high**	
		Number	**PM10 (µg/m³)**	**Number**	**PM10 (µg/m³)**	**Number**	**PM10 (µg/m³)**
Domestic H low	Industrial low	14	20	2	15	3	24
	Industrial medium	1	24	0		0	
Domestic H medium	Industrial low	8	23	2	29	1	25
	Industrial medium	3	27	1	37	0	
Domestic H high	Industrial low	32	27	18	27	4	33
	Industrial medium	5	32	3	31	0	
	Industrial high	0		2	31	0	

There is no clear relation between PM10 concentrations and the classification according to road traffic.

There is a distinct relation between the PM10 concentration and the classification according to domestic heating emissions, both for the domestic heating classification itself, and for the „low traffic" class; the relation is less clear for monitoring sites with higher traffic influence (but only few stations fall into these classes).

The relation between the classification according to industrial emissions and the PM10 concentrations is more distinct for 2003 than for 2004; however, only two stations (both in Linz) have been put in the „high" class.

6.5.4 Classification of NO_x monitoring stations on „level 2"

The test of the classification of all Austrian AQ monitoring for NO_2/NO_x sites was based on a level 2 approach for the whole of Austria, using the input data (activity data) and emission factors listed in Table 36.

Table 36: Input data and emission factors for road traffic and domestic heating, NO_x.

	Emission factor	**Area**	**Emission factor**
Local road traffic, passenger cars	Traffic census for the streets in the vicinity, partly estimated or extrapolated from other locations	Motorway	0.60 kg/km.year
		other rural roads	0.37 kg/km.year
		urban roads	0.50 kg/km.year
Local road traffic, heavy duty vehicles		Motorway	8.84 kg/km.year
		other rural roads	8.10 kg/km.year
		urban roads	10.18 kg/km.year
Domestic heating	Population within 1 km radius	Towns > 30.000 inhabitants	1.25 kg/person.year
		Near agglomerations	1.90 kg/person.year
		Rural	2.45 kg/person.year

The strongly varying emission factors for different types of urban situations and rural areas lead to much higher domestic heating emissions in small towns and rural areas compared to the level 1 approach with a uniform emission factor. Industrial sources: expert estimation (from emission data and studies on air quality) of the contribution to measured pollution level.

6.5.4.1 Class boundaries for traffic emissions

In a first approach, three classes are defined for the emission sectors road traffic, domestic heating and industry. The class boundaries for road traffic and domestic heating are derived from the distribution of the classification parameter, as depicted in Figure 34.

The „traffic emission parameter" as defined above gives, at level 2, numeric values between almost 0 and 61.4 $g/(m^{3/2} \cdot day)$ for NO_x at Austrian AQ monitoring stations. For a classification into 3 classes, class boundaries of 5 $g/(m^{3/2} \cdot day)$ and 15 $g/(m^{3/2} \cdot day)$ are proposed.

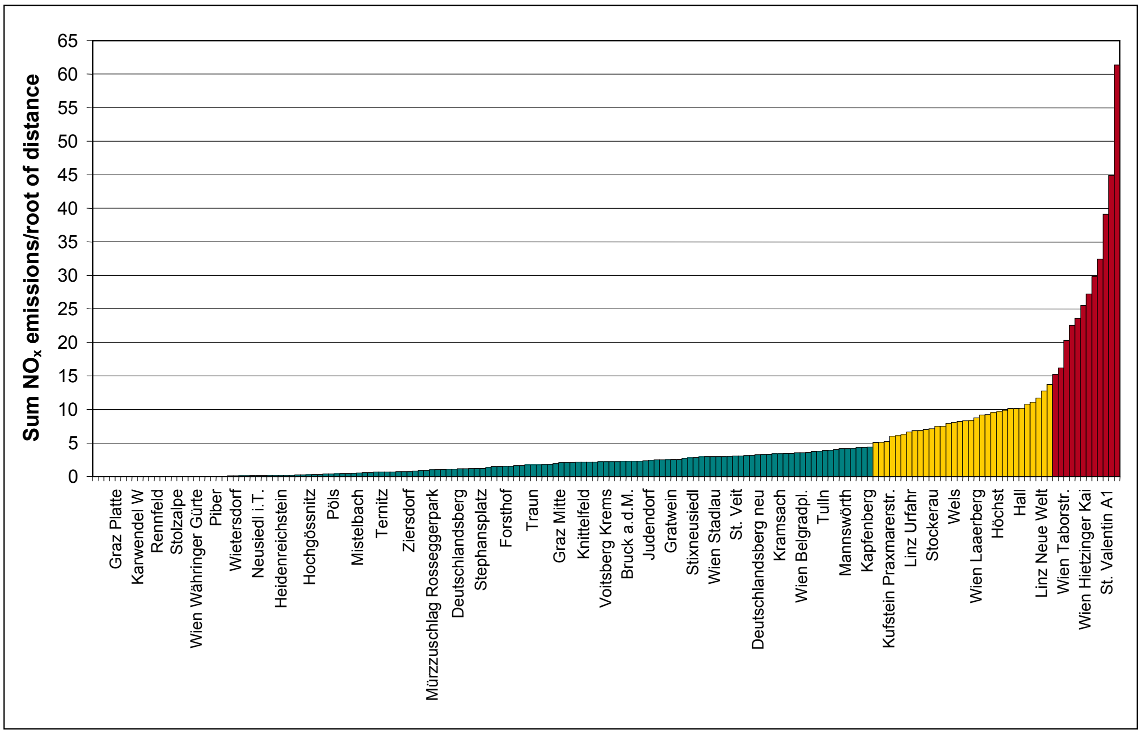

Figure 34: Distribution of the road traffic emission parameter for Austrian monitoring stations, NO_x, level 2 ($g/(m^{3/2} \cdot day)$).

6.5.4.2 Class boundaries for domestic heating emissions

The distribution of the domestic heating emissions of NO_x in the surroundings within a 1 km radius in Figure 35 suggests class boundaries at 9 and 20 t/year. A class separation at 25 t/year would also be reasonable, but lead to a rather small class above this threshold.

The differences between level 1 and level 2 are due to the higher emission factors in rural areas compared to large cities; therefore the monitoring sites with low population numbers in the surroundings have larger domestic heating emissions compared to the uniform emission factor at level 1.

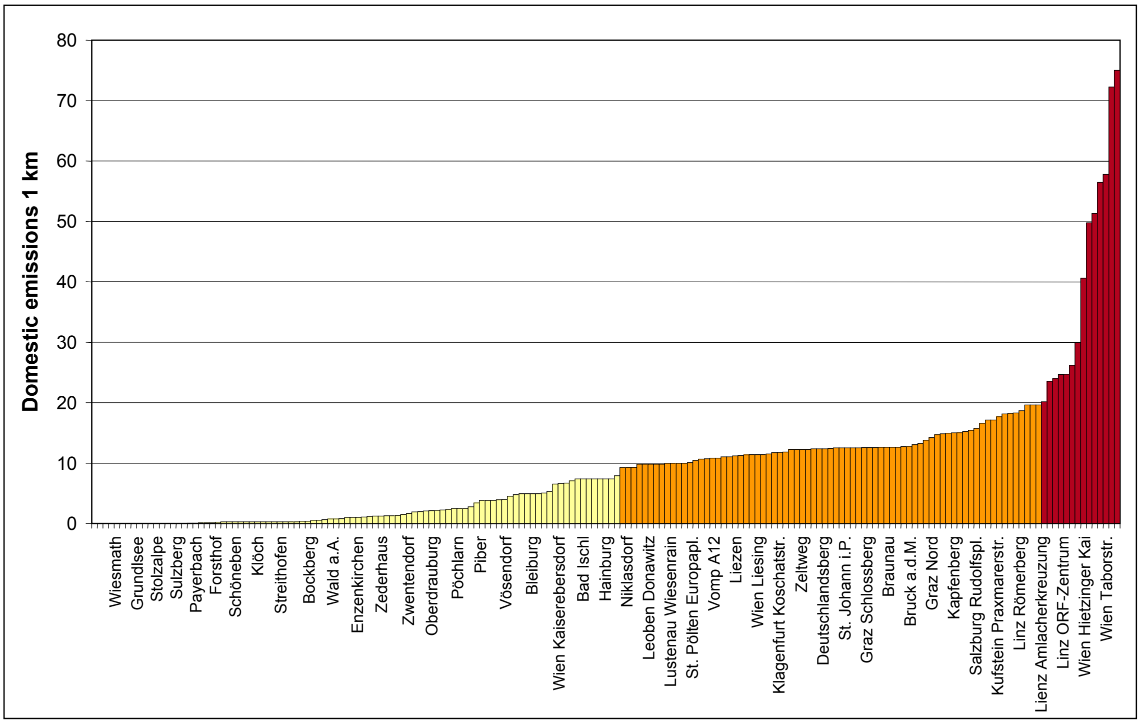

Figure 35: Distribution of NO_x domestic heating emissions, level 2.

6.5.4.3 Classification results

Table 37 lists the number of monitoring stations for each of the three classes of traffic, domestic heating and industrial emissions, and the average NO_2 concentrations for each class for 2003 and 2004 in µg/m³.

Table 38 gives a cross-classification according to traffic, domestic heating and industrial emissions of NO_x.

Table 37: Classification results for 182 Austrian NO_2 monitoring sites, separate entries for traffic, domestic heating and industrial emissions, level 2. Number of stations per class, average concentration per class for 2003 and 2004.

	Class „low"			**Class „medium"**			**Class „high"**		
	Number	**NO_2 (µg/m³)**		**Number**	**NO_2 (µg/m³)**		**Number**	**NO_2 (µg/m³)**	
		2003	2004		2003	2004		2003	2004
Traffic	95	23	24	29	37	35	12	51	51
Domestic H.	61	28	27	61	39	39	14	41	38
Industrial	127	38	36	9	34	35	0		

Table 38: Cross-classification according to traffic, domestic heating and industrial emissions of NO_x, level 2. Number of stations and average NO_2 values 2004, µg/m³.

		Traffic low		Traffic medium		Traffic high	
		Number	**NO_2 (µg/m³)**	**Number**	**NO_2 (µg/m³)**	**Number**	**NO_2 (µg/m³)**
Domestic H low	Industrial low	49	13	5	30	4	45
	Industrial medium	3	22	0		0	
Domestic H medium	Industrial low	34	23	17	36	5	52
	Industrial medium	2	32	2	39	1	53
Domestic H high	Industrial low	7	29	4	37	0	
	Industrial medium	0		1	31	2	54

Average NO_2 concentrations are clearly related to the classification according to local road emissions.

The relation of the NO_2 concentrations to the classification according to domestic heating emissions is less distinct: the medium and high class of domestic heating differ only slightly. This might be due to an underestimation of domestic heating emissions at level 2, as well as due to the fact that traffic emissions exert a major influence on urban NO_2 concentrations. In the subclass „low traffic", there is a clear relation between average NO_2 concentrations and the domestic heating classification.

The average NO_2 concentration shows no relation to the classification according to industrial emissions; the influence of these is superseded mainly by traffic contributions. In the sub-class „low traffic", and for all three classes of domestic heating emissions, the NO_2 concentrations are clearly related to the industrial emission classification.

For the monitoring sites presented in Figure 1, the modelled or estimated absolute contributions from local road traffic, domestic heating and industry to the annual mean NO_2 concentrations are given in Table 39, in order to compare the classification results with the absolute concentrations. The estimated absolute contributions given in Table 39 and the classification results presented in this chapter were derived completely independently of each other, and are therefore well suited for the evaluation of the classification method.

Table 39: Modelled or estimated absolute contributions from local road traffic, domestic heating and industry to the annual mean NO_2 concentrations at the Austrian monitoring sites Klagenfurt Koschatstraße, Klagenfurt Völkermarkterstraße, Wien Hietzinger Kai and Wien Taborstraße, µg/m³ (2005). The numbers in parentheses give the classification (0 low, 1 medium, 2 high).

	Local road traffic	Domestic heating	Industry	Annual mean
Klagenfurt Koschatstr.	2 (0)	4 (1)	3 (0)	27
Klagenfurt Völkermakterstr.	14 (1)	3 (1)	3 (1)	43
Wien Hietzinger Kai	40 (2)	<6 (2)	3 (0)	73
Wien Taborstr.	11 (1)	>6 (2)	3 (0)	43

There is a clear relation between the estimated/modelled NO_2 contribution from local road traffic and the classification: 40 µg/m³ at Hietzinger Kai is class „high", 11 to 14 µg/m³ at Taborstraße and Völkermarkterstr. „medium".

The absolute contributions from domestic heating are much smaller and estimated to be about 6 µg/m³ in Wien/Vienna and about 4 µg/m³ in Klagenfurt. However, the classification separates the sites in Wien (class „high”) from those in Klagenfurt („medium”).

The classification of Klagenfurt Völkermarkterstraße as „medium” for industrial emissions, based on expert judgement, is not reflected by the modelled contribution (and therefore not justified), which is – with 3 µg/m³ – as low as for Koschatstr.

As already stated in chapter 2.5.1, the absolute contribution from local road traffic is much higher than that from domestic heating even for stations which are classified as „high” for both categories of emissions.

6.5.5 Classification of PM10 monitoring stations on „level 2”

The test of the classification of all Austrian AQ monitoring sites for PM10 was based on a level 2 approach for the whole of Austria, using the input data (activity data) and emission factors listed in Table 40.

Table 40: Input data and emission factors for road traffic and domestic heating, PM10.

	Emission factor	Area	Emission factor
Local road traffic, passenger cars	Traffic census for the streets in the vicinity, partly estimated or extrapolated from other locations	Motorway	0.08 kg/km.year
		other rural roads	0.07 kg/km.year
		urban roads	0.09 kg/km.year
Local road traffic, heavy duty vehicles		Motorway	0.26 kg/km.year
		other rural roads	0.49 kg/km.year
		urban roads	0.88 kg/km.year
Domestic heating	Population within 1 km radius	Wien (>1.000.000 inhabitants)	0.11 kg/person.year
		Towns 100.000 – 1.000.000 inh.	0.16 kg/person.year
		Towns 20.000 – 100.000 inh.	0.25 kg/person.year
		Towns 10.000 – 20.000 inh.	0.45 kg/person.year
		Rural	0.95 kg/person.year

Industrial sources: expert estimation (from emission data and studies on air quality) of the contribution to measured pollution level.

The strongly varying emission factors for different types of urban situations and rural areas lead to much higher domestic heating emissions in small towns and rural areas compared to the level 1 approach with a uniform emission factor. For PM10, this effect is even more pronounced compared to NO_x.

6.5.5.1 Class boundaries for traffic emissions

The class boundaries for road traffic and domestic heating are derived from the distribution of the classification parameter, as depicted in Figure 36.

The „traffic emission parameter" as defined above gives, at level 2, numeric values between almost 0 and 3.9 g/(m$^{3/2\cdot}$day) for PM10 at Austrian AQ monitoring stations. For a classification into 3 classes, class boundaries of 0.4 g/(m$^{3/2\cdot}$day) (or 0.55 g/(m$^{3/2\cdot}$day)) and 1.1 g/(m$^{3/2\cdot}$day) are proposed.

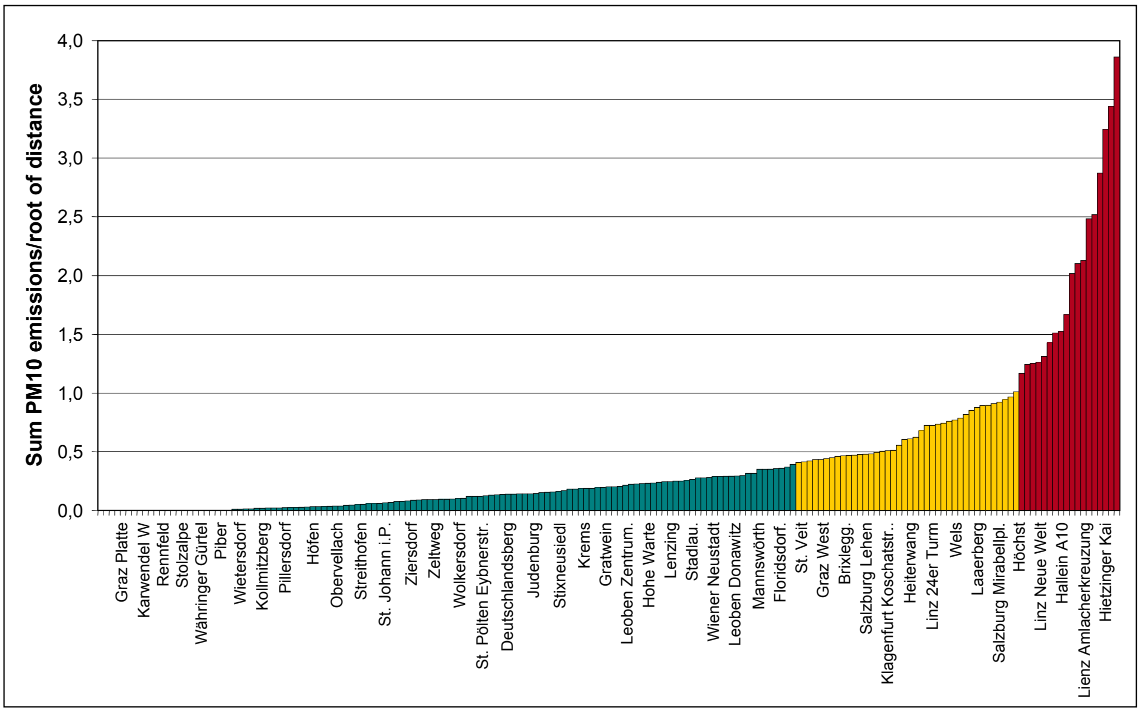

Figure 36: Distribution of the road traffic emission parameter for Austrian monitoring stations, PM10, level 2 (g/(m$^{3/2\cdot}$day)).

6.5.5.2 Class boundaries for domestic heating emissions

The distribution of the domestic heating emissions of PM10 in the surroundings within a 1 km radius in Figure 37 is completely different from the level 1 approach in Figure 33. The PM10 emission factor for rural areas (0.95 kg/person.year) is much higher than for the largest city, Wien/Vienna (0.11 kg/person.year) and the other large cities. This distinct variation of the emission factor largely overrules the population distribution, and many small towns have higher domestic heating emissions (within a circle of a 1 km radius) than even densely populated areas in the central parts of large cities.

The distribution of the level-2 domestic heating emissions in Figure 37 does not suggest clear class boundaries (except for very few monitoring sites with very high emissions). The selection of class boundaries at 1 and 3 t/year seems reasonable but somehow deliberate.

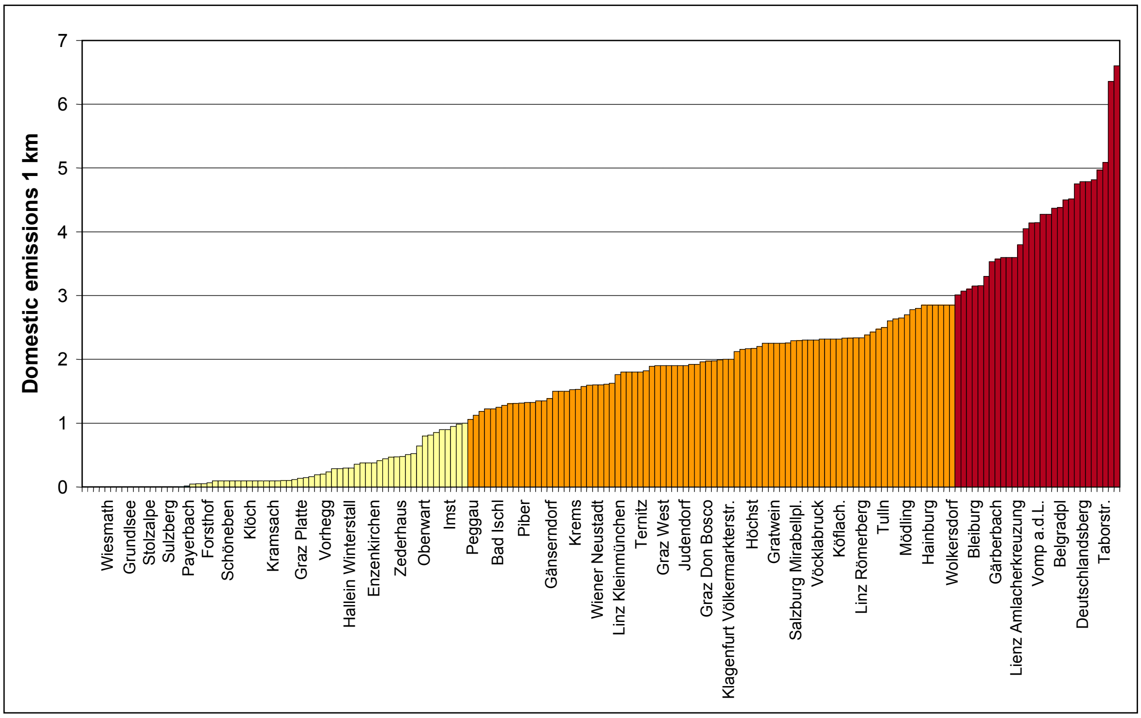

Figure 37: Distribution of domestic heating PM10 emissions, level 2 (t/year).

6.5.5.3 Classification results

Table 41lists the number of monitoring stations for each of the three classes of traffic, domestic heating and industrial emissions, and the average PM10 concentrations for each class for 2003 and 2004 in µg/m³. Table 41 gives a cross-classification according to traffic, domestic heating and industrial emissions of PM10.

Table 41: Classification results for Austrian PM10 monitoring sites, separate entries for traffic, domestic heating and industrial emissions. Number of stations per class, average concentration per class for 2003 and 2004.

	Class „low"			Class „medium"			Class „high"		
	Number	PM10 (µg/m³)		Number	PM10 (µg/m³)		Number	PM10 (µg/m³)	
		2003	2004		2003	2004		2003	2004
Traffic	54	29	25	30	33	27	15	35	32
Domestic H.	24	29	25	56	36	31	19	32	29
Industrial	84	30	26	13	36	32	2	38	31

Table 42: Cross-classification according to traffic, domestic heating and industrial emissions of PM10. Number of stations and average PM10 values 2004, µg/m³.

		Traffic low		**Traffic medium**		**Traffic high**	
		Number	**PM10 (µg/m³)**	**Number**	**PM10 (µg/m³)**	**Number**	**PM10 (µg/m³)**
Domestic H low	Industrial low	15	20	3	20	3	24
	Industrial medium	2	24	0		1	37
Domestic H medium	Industrial low	25	25	16	26	4	34
	Industrial medium	4	28	4	32	2	38
	Industrial high	0		0		1	32
Domestic H high	Industrial low	8	29	6	25	4	30
	Industrial medium	0		0			
	Industrial high	0		1	30		

The PM10 concentrations are clearly related to the classification according to local road traffic, however with smaller differences between the classes compared to NO_2. This picture is not so clear for the various sub-classes, showing obviously varying impacts from other emission sources.

The classification according to domestic heating emissions shows clearly distinct average concentrations for the low and medium class, whereas the medium and the high class do not differ. The sub-classes with low traffic influence show the clearest relation between average PM10 concentrations and the domestic heating classification.

The same can be said for the classification according to industrial emissions, but it has to be taken into consideration that the high class covers only two (urban) sites.

A comparison of the estimated absolute contributions of the emission sectors to the annual mean PM10 concentration with the classification results is given in Table 43 for the Austrian monitoring sites Wolfsberg, Imst, Klagenfurt Völkermarkterstraße, Wien Währinger Gürtel, Wien Rinnböckstraße, Wien Spittelauer Lände and Wien Liesing. These are the monitoring sites for which an estimated source apportionment of PM10 concentrations is described in chapter 2.5.1.2 and shown in Figure 2. It has to be noted that the uncertainties of the source apportionment for PM10 are much higher than for NO_2.

The estimated absolute contributions given in Table 43 and the classification results presented in this chapter were derived completely independently of each other, and are therefore well suited for the evaluation of the classification method.

In Table 43 the secondary contributions from gaseous emissions of road traffic, domestic heating and industry are not attributed to these sectors. This might be justified, since in practice it is not possible to attribute secondary particles to certain sources. Nevertheless, there is some evidence that high NO_x emission densities in Wien significantly contribute to nitrate concentrations. The „allocation” of secondary particles to certain emissions is the subject of ongoing research.

Table 43: Estimated absolute contributions from local road traffic, domestic heating and industry to the annual mean PM10 concentrations at the Austrian monitoring sites Wolfsberg, Imst, Klagenfurt Völkermarkterstraße, Wien Währinger Gürtel, Wien Rinnböckstraße, Wien Spittelauer Lände and Wien Liesing, µg/m³ (2005, Spittelauer Lände 2000/01). The numbers in parentheses give the classification (0 low, 1 medium, 2 high).

	Local road traffic	**Domestic heating**	**Industry**	**Secon-dary**	**Regional**	**Annual mean**
Wolfsberg	9 (1)	12 (1)	5 (1)	8	0	35
Imst	7 (2)	1 (0)	0 (0)		14[22]	29
Klagenfurt Völkermarkterstr.	12 (2)	10 (1)	2 (1)	7	8	38
Wien Währinger Gürtel	5 (0)	2 (2)	0 (0)		23[22]	30
Wien Rinnböckstraße	13 (1)	2 (1)	0 (0)		23[22]	40
Wien Spittelauer Lände	25 (2)	2 (1)	0 (0)		23[22]	53
Wien Liesing	4 (1)	1 (0)	5 (1)		23[22]	34

Table 43 clearly shows that the classification results do not well correspond to the estimated contributions from each emission sector, even when keeping in mind the large uncertainties of the underlying source apportionment.

Some mismatches can be interpreted. The overestimation of local road traffic in Imst (class „high", but with a contribution of only about 7 µg/m³) compared to Wien Rinnböckstraße (class „medium", but with a contribution of about 13 µg/m³) can be ascribed to different traffic situations which are still not sufficiently considered in the calculation of PM10 emissions. Imst is located near the A12 motorway, whereas Wien Rinnböckstraße is an urban station, and it might be argued that PM10 emissions on the motorway are overestimated or, on the other hand, that PM10 emission are underestimated in the urban situation.

The huge mismatches regarding domestic heating emissions can be attributed to various reasons:

- underestimation of per capita emissions in Wolfsberg (a town with 25,000 inhabitants), perhaps higher „rural type emissions" would be more appropriate;
- the estimated contribution of domestic heating emissions to PM10 levels in Wolfsberg represents the total Lavanttal and not only emissions within 1 km, which might be much lower.
- the contributions of domestic heating in Wien given in Table 43 are not modelled, but attributed equally to all central urban monitoring sites according to the share of domestic heating emissions in the total PM10 emissions in Wien.

Thus there might be an underestimation at Wien Währinger Gürtel compared to Klagenfurt and Wolfsberg, but the classification results still seem to overestimate the domestic heating inpact in Wien.

It should be noted that a calculation of domestic heating emissions in Wolfsberg on the basis the EEA population data (with 3500 inhabitants within 1 km around the monitoring site, compared to 8000 in the 2.5 km grid) would put Wolfsberg even in the class „low". On the other hand, using the EEA population data would put Liesing in the class „medium" for domestic heating emissions.

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[22] no separation of regional and secondary aerosols.

The „medium" classification according to industrial emissions of Wolfsberg, Klagenfurt Völkermarkterstraße and Wien Liesing corresponds to quite low absolute contributions between 2 and 5 µg/m³. Applying the criteria given in chapter 3.2.5, which proposes a lower class boundary of 10 µg/m³ for „medium" industrial impact, all these sites would be classified as „low".

In Chapter 3.2.6, considering the rural background PM10 concentration is discussed as an additional classification criterion, as well as class boundaries of 10 and 20 µg/m³ to create three classes. By applying this additional criterion, Wien would be classified under „high rural PM10 background", Imst under „medium", and Klagenfurt and Wolfsberg under „low". These results are, however, tentative, since there is no clear distinction between secondary aerosols formed from precursors emitted in the respective town and the regional background.

It can be concluded from this comparison that large uncertainties in PM10 emissions are likely to hamper a fairly accurate classification according to PM10 emissions.

6.5.6 Comparison of domestic heating emissions: gridded population data on 2.5 km vs. EEA data set

The population distribution for Austria, used for the estimation of domestic heating emissions in the chapters above is available on a 2.5 km grid. The results of the domestic heating data obtained from these population data are compared with the population data provided by EEA.[23] The EEA data are available for polygonal areas with high resolution (approx. 100 m); within quite large areas, uniform – and not really realistic –population densities are given.

The EEA population map is based on the CORINE Landcover areas 1.1.1, 1.1.2, 1.4.1 and 1.4.1, but it should be kept in mind that CLC areas 1.4.1 „Green urban areas" and 1.4.2 „Sport and leisure facilities" are in fact uninhabited areas.

Figure 38 and Figure 39 compare the population distribution in the region of Wien/Vienna for both data sets.

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[23] http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=830. ; GALLEGO AND PEDELL (2001).

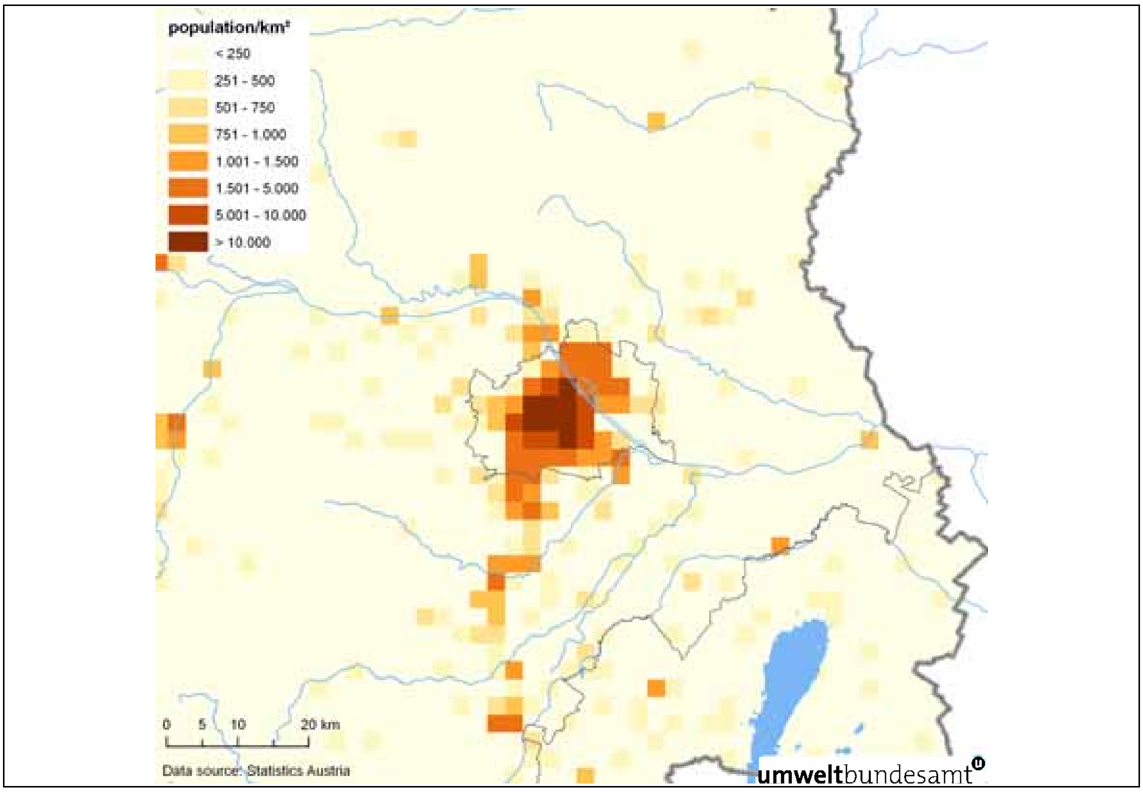

Figure 38: Population density in Wien/Vienna, gridded data at 2.5 km resolution.

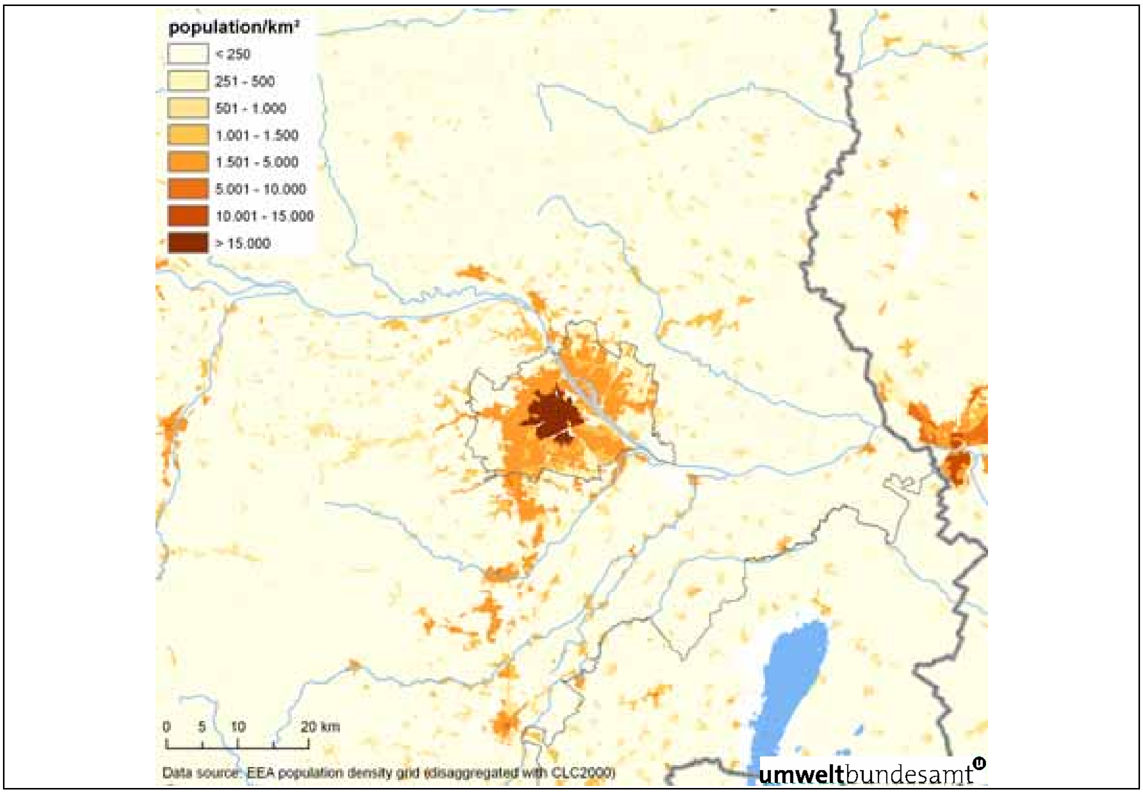

Figure 39: Population density in Wien/Vienna, EEA data.

The distribution of NO_x and PM10 emissions from domestic heating (level 2 approach), calculated by the EEA population data, are given in Figure 40 and Figure 41.

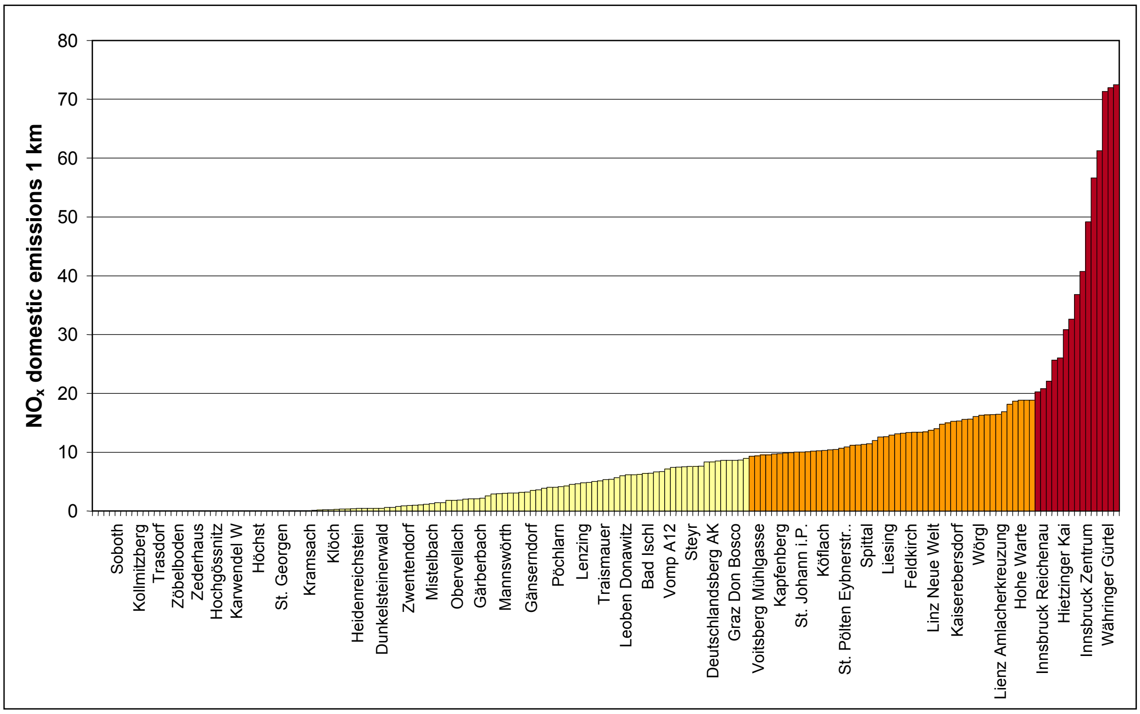

Figure 40: Domestic heating emissions for NO$_x$ based on EEA population data, level 2.

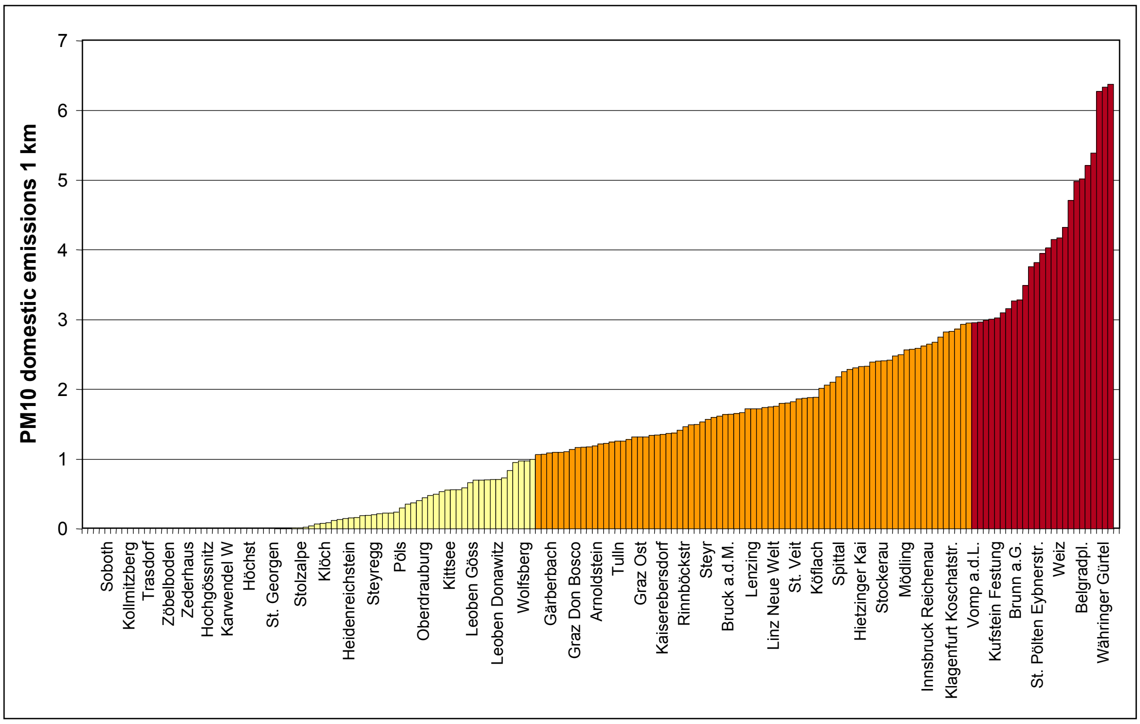

Figure 41: Domestic heating emissions for PM10 based on EEA population data, level 2.

The distribution of the NO$_x$ emissions based on the EEA population data rather suggest class boundaries (for three classes) at 12 and 20 t/year, compared to 9 and 20 t/year for the approach based on the 2.5 km gridded population. Anyhow, the class boundary at 9 or 12 t/year is not at all distinct.

The distribution of the PM10 emissions based on the EEA population data suggests class boundaries at about 0.8, 2 and 3 t/year, but this selection seems somehow deliberate.

A comparison of the classification of domestic heating NO_x and PM10 emissions is given in Table 44. The mismatches of the classification – using the class boundaries derived for the level 2 approach based on the 2.5 km gridded population data – concern 20% of the monitoring stations both for NO_x and PM10 emissions. The difference most frequently found concerns stations which are in the class „medium" based on the 2.5 km gridded population, and in the class „low" based on the EEA population data.

Higher population numbers and therefore emissions compared to the EEA population data – calculated on the 2.5 km population data – are mostly found in suburban locations in large cities. By contrast, the EEA population data in small towns give much higher population numbers and emissions than the 2.5 km gridded data.

This is to be expected as the 2.5 km grid in fact comprises the population outside the 1 km circle which is used as classification parameter, and is therefore likely to overestimate the population in suburban locations in large urban areas and to underestimate the population in small towns.

Table 44: Comparison of the classification of domestic heating NO_x and PM10 emissions, based on the population distribution on a 2.5 km grid and the EEA population data set.

Classification based upon		**Number of stations**	
2.5 km grid	**EEA data**	**NO_x**	**PM10**
low	low	90	65
low	medium	3	3
medium	low	25	13
medium	medium	43	65
medium	high	5	7
high	medium	4	12
high	high	10	15

6.5.7 Comparison of the classification of NO_x and PM10 monitoring sites – level 1 vs. level 2

6.5.7.1 Comparison of the traffic emission parameter between level 1 and 2

The traffic emission parameter calculated on level 1 for NO_x (uniform emission factor for all roads) and on level 2 (specific emission factor for motorways, other rural and urban roads, Table 33) correlate quite closely. The coefficient of determination is nearly 1. The level 2 emissions are slightly higher than the level 1 emissions.

For PM10, the differences between emission factors for different roads are higher (see Table 40), with quite low emission factors for motorways and high emission factors on urban roads. Therefore the discrepancies between level 1 and level 2 are higher, yielding a coefficient of determination of 0.91. Calculated at level 2, urban locations are affected by higher, rural locations by lower PM10 emissions compared to level 1.

6.5.7.2 Comparison of the domestic heating emissions between level 1 and 2

The different NO_x emission factors (emission per person) from domestic heating under the spatially differentiated level 2 approach (see Table 36) lead to lower NO_x emissions in larger towns and vice versa. The variation of the emission factor is, however, small enough (compared to PM10) so that large towns still have higher emissions from domestic heating compared to rural areas and small towns.

Emissions for PM10 (emissions per person see Table 40) present a completely different picture. In the level 2 approach, domestic heating emissions in small towns are similar to those in agglomerations, which show emissions that are very much lower compared to the level 1 approach.

6.5.7.3 Comparison of the NO_x classification

The level 1 approach underestimates the traffic emissions for most AQ monitoring sites compared to level 2. 138 Austrian AQ monitoring sites (not all of these measure NO_2, and therefore the tables in the above chapters list fewer monitoring stations) are classified in the „low traffic" class both with level 1 and 2; three „low traffic, level 2" sites are medium traffic at level 1. From 31 „medium traffic, level 2" sites, 29 are also medium traffic sites for level 1, two are high traffic sites. All 10 „high traffic, level 2" sites are also high traffic sites at level 1.

A comparison of the domestic heating NO_x emissions for the level 1 and 2 approaches is given in Table 45. The major mismatches concern underestimations under the level 1 approach in a multitude of towns with 10,000 to 20,000 inhabitants, which are „medium" in level 2 and „low" in level 1. On the other hand, several sites in Wien and Linz, and also some other larger towns are classified as „high" in the level 1 approach and „medium" at level 2.

Table 45: Comparison of the classification of Austrian NO_2 monitoring sites according to domestic heating emissions, level 1 vs. level 2 approaches.

Level 2 classification	Level 1 classification	Number of sites
low	low	92
low	medium	1
medium	low	34
medium	medium	34
medium	high	7
high	medium	1
high	high	13

However, the groups classified as „medium" for both level 1 and 2, „medium, level 2" and „high level 1" as well as „high" for both levels show almost identical average NO_2 concentrations (2004) of about 35 µg/m³. Different classes of traffic influence can be found in these groups; in the „medium/medium group" there are 63% sites in traffic class medium or high (17% high), in the „medium/high group" 50% are in traffic class medium (no high), in the „high/high group" only 38% traffic medium. The almost equal NO_2 concentrations in these groups can be attributed to the different contributions from traffic which obviously „outweigh" the differences of domestic heating emissions.

6.5.7.4 Comparison of the PM10 classification

All 125 AQ monitoring sites classified as „traffic low, level 2” are also „low” for the level 1 approach.

14 sites which are „traffic medium, level 2” are classified as „traffic low” for level 1, 26 sites as „traffic medium” with both approaches.

Similarly, seven „traffic high, level 2” sites are classified „medium” for level 1, 11 sites as „traffic high” with both approaches.

The discrepancies are found for urban monitoring sites, where the level 2 emission factors are much higher than the (averaged) level 1 emission factors.

Many more mismatches occur for the domestic heating emission classification, as can be expected from the large spatial variation of emissions per person used for the level 1 approach. The distribution of the classes for the level 1 and 2 approaches are compared in Table 46.

Five suburban monitoring sites are classified as „low domestic heating, level 2” but in the higher classes under the level 1 approach. The major mismatch concerns the 64 sites „medium domestic heating, level 2”, which have „high” domestic heating emissions at level 1. These are urban sites in towns with populations between 10,000 and 150,000 inhabitants, and also suburban sites in larger towns.

Table 46: Comparison of the classification of Austrian PM10 monitoring sites according to domestic heating emissions, level 1 vs. level 2 approach.

Level 2 classification	Level 1 classification	Number of sites
low	low	62
low	medium	2
low	high	3
medium	low	1
medium	medium	21
medium	high	64
high	medium	3
high	high	26

6.5.8 Comparison of the classification of NO_x and PM10 monitoring sites – level 2 vs. level 3

For selected regions, level 3 emissions are available from emission inventories and can be used for a comparison of the level 2 and level 3 approaches.

6.5.8.1 NO_x traffic Wien

The level 2 emissions of NO_x for Wien (Vienna) are calculated from traffic volume data. The newly available emission inventory gives more accurate emission data, which are compared to the level 2 data in Table 47.

Table 47: Comparison of road traffic NO_x emissions (kg/km.day) in the immediate vicinity of monitoring stations in Wien.

Station	**Level 2**	**Level 3**
Belgradpl.	4920	5426
Floridsdorf	19680	16553
Hietzinger Kai	29506	27872
Hohe Warte	4920	5151
Kaiserebersdorf	2952	2952
Kendlerstr.	4920	6265
Laaerberg	25190	30239
Liesing	7808	3711
Rinnböckstr.	2952	1195
Schafbergbad	1968	1968
Stadlau	1968	1968
Stephansplatz	984	984
Taborstr.	8062	6728
Währinger Gürtel	4920	4920

Differences can be attributed to different total traffic volumes, different HDV shares or different emission factors, depending on the traffic situation.

The classification presented in chapter 6.5.4 for the level 2 approach differs only for one station (Liesing) from the level 3 approach. In the case of Liesing, the differences are not due to local road traffic, but to two major roads at distances of 100 m and 250 m, where the level 2 approach gives much higher NO_x emissions (due to an overestimation of the traffic volume) compared to the emission inventory. The level 2 data put Liesing into class „medium", the level 3 data into class „low".

The traffic emission parameter is overestimated by 84% both at the sites Hohe Warte (not traffic influenced, class low) and Liesing, and by 38% at Taborstraße (class medium).

6.5.8.2 NO_x domestic heating Wien

Table 48 gives a comparison of the NO_x emissions within a circle of a 1 km radius around the monitoring sites in Wien from different data sources:

- the emission inventory (the most accurate data set),
- calculated from the population distribution gridded with 2.5 km resolution, using average emissions of 1.25 t/year per capita,
- calculated from the EEA population distribution map, using average emissions of 1.25 t/year per capita.

Table 48: Comparison of the NO_x domestic heating emissions within a 1 km circle around the monitoring sites in Wien (t per year).

Monitoring site	Emission inventory	Calculated from population	
		2.5 km grid	EEA data
Belgradpl.	35	50	57
Floridsdorf	23	18	16
Gaudenzdorf	52	72	72
Hermannskogel	1	1	0
Hietzinger Kai	28	41	26
Hohe Warte	23	26	19
Kaiserebersdorf	2	5	15
Kendlerstr.	27	51	49
Laaerberg	8	30	13
Liesing	6	11	13
Lobau	0	0	0
Rinnböckstr.	8	25	16
Schafbergbad	12	16	15
Stadlau	11	11	15
Stephansplatz	32	56	72
Taborstr.	56	58	61
Währinger Gürtel	60	75	71

The relative discrepancies between the emission inventory and the data estimated from the population distribution range between about -30% (Floridsdorf, EEA data) and + 300% (Laaerberg, 2.5 km gridded data). The numbers for Kaiserebersdorf are not comparable since the 1 km circle is partly outside the territory of Wien and not covered by the emission inventory. The most severe relative mismatches concern the monitoring site Lobau, which covers almost uninhabited suburban areas, and the differences are therefore not significant.

Class boundaries for the three classes are 9 and 20 t/year. Based on the emission inventory, the monitoring sites Belgradplatz, Floridsdorf, Gaudenzdorf, Hietzinger Kai, Hohe Warte, Kendlerstraße, Stephansplatz, Taborstraße und Währinger Gürtel would be classified as „high". The emissions around Floridsdorf are underestimated by the emissions based on the population distribution, and therefore the classification of this site would be „medium". For Hohe Warte, the classification using the 2.5 km gridded population gives a good match, the EEA data underestimates it.

On the other hand, the population based emissions overestimate the classification for Laaerberg and Rinnböckstraße, where the emission inventory gives class „low", the 2.5 gridded population data „high", the EEA data „medium".

The suburban sites Schafbergbad and Stadlau are classified as „medium" based on the emission inventory, which is the same as for population based emissions.

The suburban sites Hermannskogel, Kaiserebersdorf, Laaerberg, Liesing, Lobau and Rinnböckstraße are classified „low" using the emission inventory, but the population based emissions lead to a large overestimation except for the semi-rural sites Hermannskogel and Lobau. These mismatches can mainly be attributed to shortcomings in the allocation of the population, which is, of course, insufficient on a 2.5 km grid (related to a circle with a 2 km diameter in which the emissions are calculated), especially around Laaerberg and Liesing, where large commercial and recreational areas can be found near the monitoring sites. But an allocation of the population on the EEA map with uniform population density in the CLC area „discontinuous urban fabric" – which also covers weekend house settlements – also leads to overestimations of the population in suburban areas.

6.5.8.3 Domestic heating Oberösterreich (Upper Austria)

The domestic heating emissions (NO_x and PM10) within a circle of 1 km around the AQ monitoring sites in Oberösterreich (Federal Province of Upper Austria) calculated at the level 2 approach – based upon the population distribution with emissions per capita depending on the number of inhabitants in the town – were compared with emissions taken directly from the emission inventory (level 3) of the Federal Province of Oberösterreich.

The NO_x and PM10 emissions for both data sources are listed in Table 49. Despite the fact that the emissions per person which are a major input for the level 2 calculations were derived using data from the emission inventory Oberösterreich, severe mismatches can be observed especially for PM10, and to a lesser extent for NO_x (where emissions per person vary less).

Table 49: Comparison of NO_x and PM10 emissions (1 km circle around the monitoring sites) in Oberösterreich – level 2 vs. level 3 (emission inventory), t/year.

	NO_x (t/year)		**PM10 (t/year)**	
Station	**Level 2**	**Level 3**	**Level 2**	**Level 3**
Bad Ischl	7	3	1.2	0.4
Braunau	13	10	2.3	2.3
Enns	2	2	0.5	0.4
Enzenkirchen	1	1	0.4	0.3
Grünbach	0	0	0.0	0.2
Lenzing	5	4	1.9	0.7
Linz 24er Turm	19	11	2.4	1.3
Linz Kleinmünchen	13	10	1.6	1.4
Linz Neue Welt	13	9	1.6	1.4
Linz ORF-Zentrum	25	28	3.2	4.0
Linz Römerberg	18	24	2.3	3.3
Linz Urfahr	14	26	1.8	2.9
Schöneben	0	0	0.1	0.1
Steyr	7	8	1.3	3.1
Steyregg	4	2	1.9	0.4
Traun	11	14	1.5	1.9
Vöcklabruck	13	3	2.3	1.1
Wels	11	12	2.2	1.7
Zöbelboden	0	0	0	0

The mismatches can be attributed to two reasons:

- Shortcomings in the spatial allocation of the population. This leads to an underestimation of domestic heating emissions in central parts of the agglomeration Linz and in Steyr, and to overestimations in suburban locations of Linz (24er Turm) and smaller towns (Bad Ischl).

- Discrepancies between emissions per person. Average PM10 emissions per person in classes of towns within a certain population range differ in some cases widely from the actual amount, which leads to overestimations e.g. in Vöcklabruck and Wels and underestimations in Steyr.

6.5.8.4 Klagenfurt, domestic heating

The emission inventory for the city of Klagenfurt allows a comparison with the NO_x and PM10 emissions from domestic heating calculated from the population number. The „level 2" approach based on the population can be based on the EEA population data as well as on the 2.5 km gridded population map available in Austria. The results are compared in Table 50.

NO_x emissions in the surroundings of Klagenfurt Koschatstraße are slightly underestimated by the level 2 approach based on population at 2.5 km resolution, but overestimated using the EEA population data. This is the case especially for Klagenfurt Völkermarkterstraße with an overestimation of almost 60%.

PM10 emissions are underestimated by the level 2 approach in any case, which can be clearly attributed to an underestimation of per capita emissions. The per capita emissions are derived from a relation between the population of a town and emission inventory data for Wien and Upper Austria (Oberösterreich), which, as can be seen, cannot easily be extrapolated to Klagenfurt.

Table 50: NO_x and PM10 emissions (t/year) within a 1 km radius around the monitoring stations Klagenfurt Koschatstraße and Klagenfurt Völkermarkterstraße

	NO_x			**PM10**		
	Population 2.5 km	**Population EEA**	**Emission inventory**	**Population 2.5 km**	**Population EEA**	**Emission inventory**
Koschatstr.	11.5	13.7	12.8	2.3	2.7	3.6
Völkermarkterstr.	10.0	14.8	8.7	2.0	3.0	3.8

The level 2 classification puts both sites in Klagenfurt (NO_x and PM10) into the class „medium", using the class boundaries proposed in chapter 6.5.4 and 6.5.5.

The level 3 approach, using the real emission inventory data, might put Klagenfurt Völkermarkterstraße below the class boundary of 9 t/year for NO_x.

On the other hand, a classification using the emission inventory puts both sites in the class „high" for PM10.

6.5.8.5 Traffic emissions: Street emissions vs. total emissions within a circle around the monitoring site

Based upon the emission inventory of Oberösterreich, the total road traffic emissions of NO_x within a circle of a 1 km radius around the AQ monitoring sites were compared with the road traffic emission parameter calculated at level 2 (Figure 42).

A comparison of the road traffic emission parameter (level 2) with the total emissions within 1 km around the monitoring sites gives a huge mismatch for the monitoring site Enns near the A1 motorway. This is because at Enns, road traffic emissions within a circle of 1 km are quite low, apart from one motorway next to the monitoring station. On the other hand, the traffic emission parameter, which depends on the distance between monitoring station and motorway, is very high.

A better agreement can be achieved for urban sites. The total NO_x road traffic emissions within a 1 km circle around the seven monitoring stations which are classified as „medium" (in Linz and Wels) are between 79 and 121 t, and the traffic emission parameter ranges between 5,178 and 11,685 kg/√km.day. The highest emissions around a „low traffic" site amount to 71 t (Traun), and the traffic emission parameter is 1,635 kg/√km.day.

The total road traffic emissions within a distance of some km around a monitoring site more or less characterise the urbanisation of the area. They do not well represent the impact of traffic emissions on the measurement site nearby.

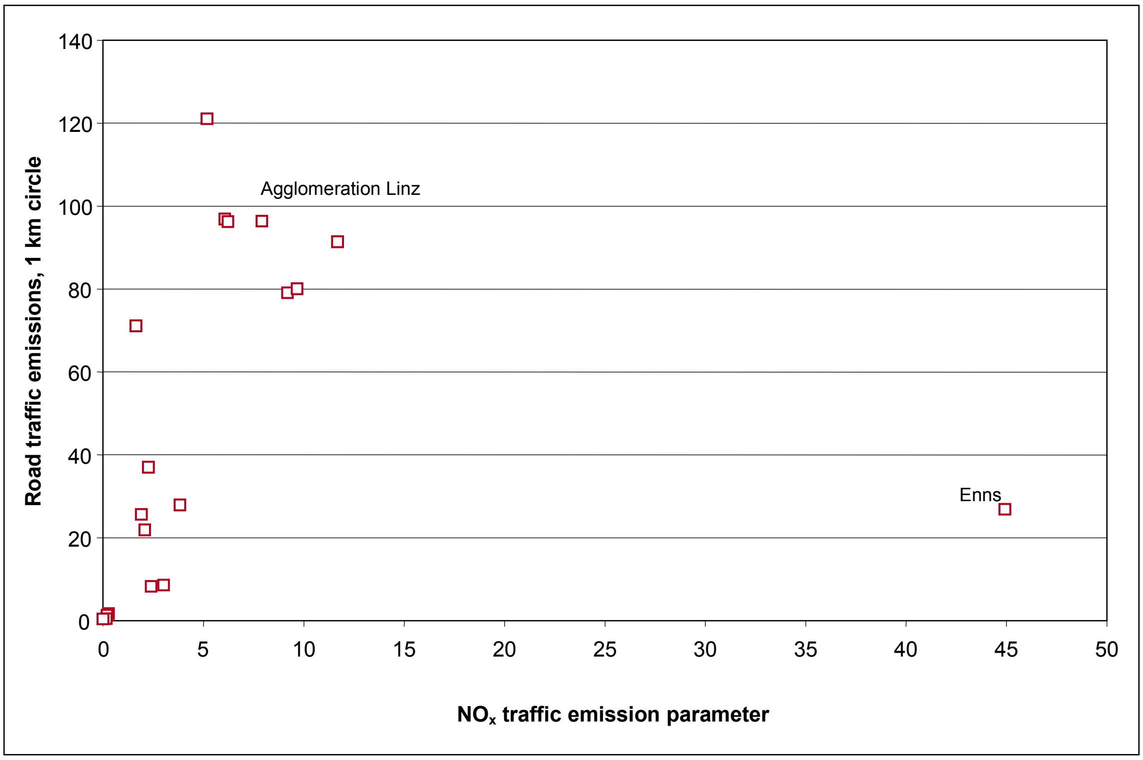

Figure 42: Comparison of road traffic emission parameter and total road traffic emissions in 1 km radius around AQ monitoring sites in Oberösterreich (Upper Austria).

6.5.9 Classification of ozone monitoring stations

According to chapter 2.5.2, the Austrian Ozone monitoring stations are classified according to the local traffic NO_x emissions, the topographic situation and the regional ozone formation potential.

As a first step, three classes for the parameter „exposure (mountain, plain, valley) and three classes for the influence of traffic emissions were used. The results of this classification – number of monitoring stations per class and average of the maximum daily 8-hour mean values – are given in Table 51 separately for each classification criterion, and in Table 52 for each of the 18 classes which result from the classification criteria.

Table 51: Classification results for Austrian Ozone monitoring sites, separate entries for traffic NO_x emissions, the topographic influence (mountain, plain, valley) and the regional ozone formation potential. For 2003 and 2004, the average daily maximum 8-hour mean value is given in µg/m^3.

	Class „low”			**Class „medium”**			**Class „high”**		
	Number	**Max 8hr O_3 (µg/m^3)**		**Number**	**Max 8hr O_3 (µg/m^3)**		**Number**	**Max 8hr O_3 (µg/m^3)**	
		2003	**2004**		**2003**	**2004**		**2003**	**2004**
Traffic NO_x	104	143	119	6	131	110	4	125	103
Exposure	35	133	111	34	136	112	45	148	125
Ozone formation	77	132	111	37	146	120			

Table 52: Cross-classification of Austrian ozone monitoring stations according to traffic NO_x emissions, the topographic influence (mountain, plain, valley) and the regional ozone formation potential. For 2004, the average daily maximum 8-hour mean value is given in µg/m^3.

		Traffic NO_x low		**Traffic NO_x medium**		**Traffic NO_x high**	
		Number	**Max 8hr O_3 (µg/m^3)**	**Number**	**Max 8hr O_3 (µg/m^3)**	**Number**	**Max 8hr O_3 (µg/m^3)**
Valley, basin	Low ozone formation	30	111	3	106	1	108
	High ozone formation	1	120	0		0	
Plain	Low ozone formation	4	117	0		0	
	High ozone formation	24	117	3	115	3	98
Mountain	Low ozone formation	36	123	0		0	
	High ozone formation	9	126	0		0	

The broad majority of the Austrian ozone monitoring stations is affected by low local traffic emissions, and these show distinctly higher averaged daily maximum 8-hour mean values (143 µg/m^3 in 2003) compared to the ozone monitoring stations with medium (131 µg/m^3) and high (125 µg/m^3) local NO_x emissions from traffic.

The ozone monitoring sites are fairly evenly distributed across the classes regarding the topographic situation: 31% in valleys or basins, 30% on flat terrain and 39% on hilly or mountainous terrain. The latter, in exposed locations, have distinctly higher average daily maximum 8-hour mean values (148 µg/m^3 in 2003) compared to those on flat terrain (136 µg/m^3) and in valleys/basins (133 µg/m^3). The differences between flat terrain and valleys/basins are, however, very small.

32% of the monitoring sites – in north-eastern Austria around the agglomeration Wien – are classified as those with high regional ozone formation potential and have distinctly higher average daily maximum 8-hour mean values (146 µg/m^3 in 2003) compared to the other sites (132 µg/m^3).

The small differences between the classes „medium traffic" and „high traffic" as well as the exposure classes „valley, basin" and „plain" justify the merging of these classes. Therefore, only two classes of exposure (exposed and non-exposed) are proposed, and the „medium" and „high traffic" sites – which cover only a small part of the Austrian ozone monitoring sites – are put into one class.

6.5.10 Test of surrogate data: Corine Landcover

The test of the Corine Landcover (CLC) data as a surrogate input for the calculation of road traffic, domestic heating and industrial emissions proved that these data are of no use for the proposed classification.

- The road network is not at all sufficiently represented in the Corine Landcover data set.
- The land use categories 1.1.1 and 1.1.2 (continuous and discontinuous urban fabric) are not very well correlated with the population, especially in areas with a high population density (see Figure 43).
- The land use categories related to industrial and commercial activities, 1.2, give no information about real emissions.

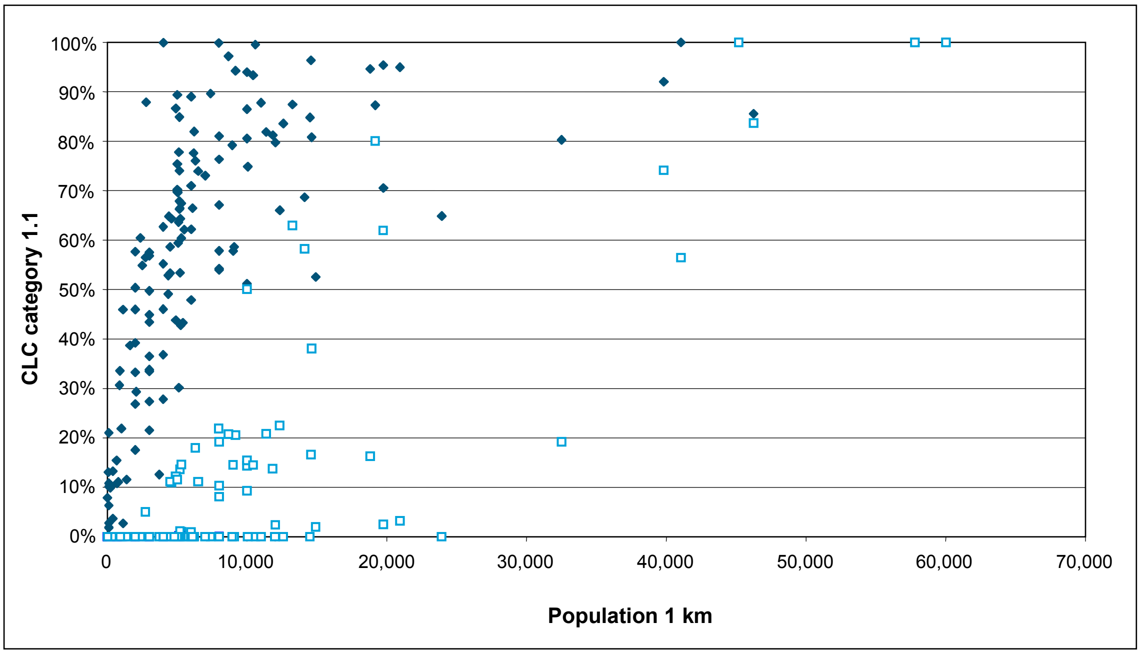

Figure 43: Relation of population within a 1 km radius to the percentage of land use categories 1.1.1 („continuous urban fabric", blue squares) and the sum of 1.1.1 and 1.1.2 („continuous and discontinuous urban fabric", dark diamonds) for Austrian monitoring sites.

6.5.11 Test of surrogate data: TeleAtlas roads

The TeleAtlas data set provides information on the road network, given as different Functional Road Classes (FRC), starting at class „0" with motorways. A first screening of the Austrian road network shows that major roads with significant traffic emissions cover approximately the FRCs 0 to 3.

A more detailed analysis of the length of roads of different FRCs in the vicinity of monitoring stations (radius 10 m and 100 m), however, reveals that the relation between the presence of roads of a high functional road class and local NO_x and PM10 emissions is quite poor.

These mismatches can mainly be attributed to the fact that the FRC is not really related to the actual traffic volume on a road, and also to small inaccuracies in the geographical location of the TeleAtlas data. Since the influence of traffic emissions on a monitoring site requires an accuracy of a scale of 10 m, even small mismatches in GIS locations between road and monitoring site make any combination of TeleAtlas road information and monitoring site location impossible.

The analysis shows that only one monitoring site in Austria (of 182 sites) is located within a 10 m distance from a FRC 0 road (Vomp at the A12 motorway): only 10 stations are within a 10 m distance from a road of a FRC up to 2.

44 stations are located within a radius of 100 m from a road of a FRC up to 3. This group of stations covers most of the urban and rural traffic related stations, and also stations with are distinctly to be classified as urban background sites or are located in small settlements without major traffic influence.

As can be seen from Figure 44, the relation between the traffic emission parameter (according to chapter 3.2) which is used for the classification of the impact of local road traffic emissions, and the total length of road of a FRC 0 to 3 within a circle of 10 m and 100 m around the Austrian monitoring sites is poor.

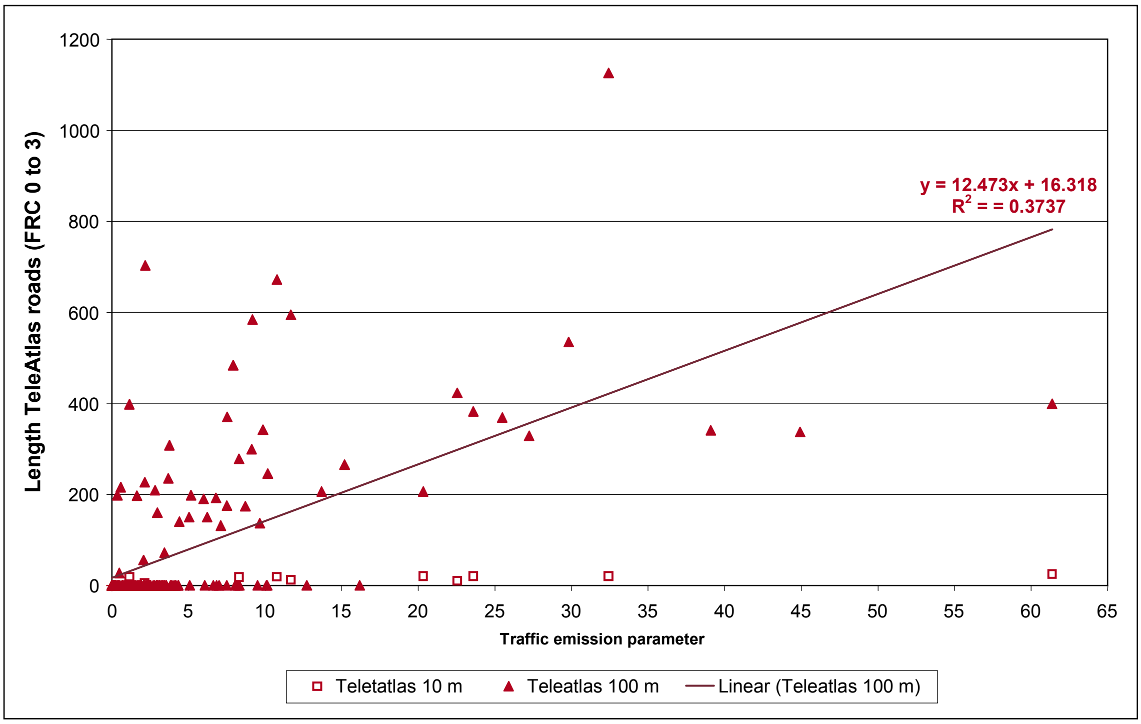

Figure 44: Relation of the traffic emission parameter (NO_x emissions/√distance, unit g/m3/2.day)) to the length of TeleAtlas roads of FRCs 0 to 3, Austria.

Compared to the classification according to NO_x emissions from local road traffic (see chapter 6.5.4), all monitoring stations classified as „high” are related to a length of over 200 m of FRC 0-3 roads within a circle of 100 m radius. But also seven sites (Eisenstadt, Wolfsberg, Tulln, St. Johann i.P., Voitsberg Mühlgasse, Bludenz and Wien Floridsdorf) classified as „low” have more than 2 FRC 0-3 roads within a circle of 100 m radius.

As an example, Figure 45 shows the town Innsbruck where no road of a FRC 0-3 crosses the city: Therefore the monitoring site Reichenau, which is classified as „medium" regarding traffic influence, is quite remote from any FRC 0-3 road.

In conclusion, teleatlas road data are not sufficient to serve as surrogate data for road traffic emissions, because they do not reflect actual traffic volumes and because of their limited spatial accuracy.

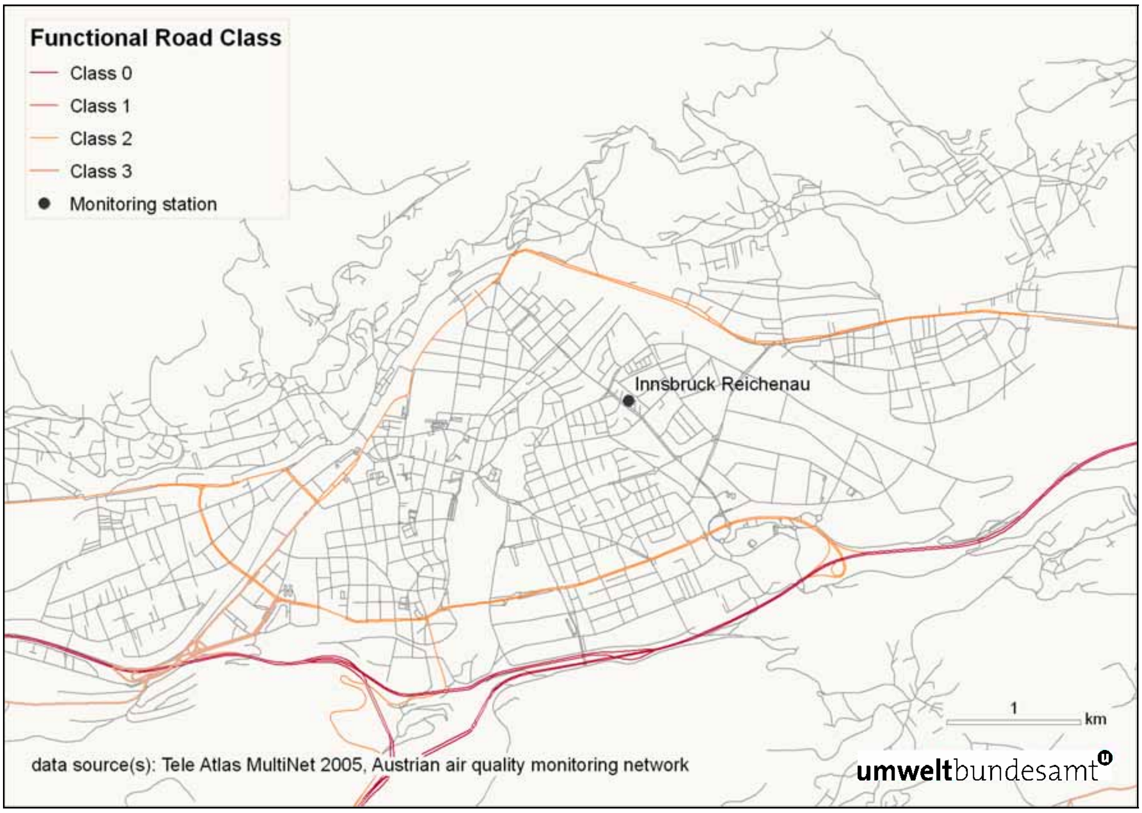

Figure 45: TeleAtlas FRC 0-3 roads in Innsbruck.

6.5.12 Comparison of NO_x and PM10 classification

The classification of the influence of NO_x and PM10 emissions from road traffic and domestic heating was performed independently, with class boundaries derived from the distribution of the respective emission parameter at the Austrian AQ monitoring sites – a selection which is somehow deliberate especially for PM10 domestic heating emissions.

The classification results (level 2 approach) for NO_x and PM10 for the Austrian AQ monitoring sites are listed in Table 53. The large majority (124 stations) of the 183 sites is „low" both for NO_x and PM10 road traffic emissions. 148 sites (81%) are in the same class for NO_x and PM10 emissions.

The mismatches concern 14 sites with „low NO_x" and „medium PM10" road traffic emissions, mainly urban locations in small and medium towns and suburban locations in agglomerations. Seven sites are classified as „medium NO_x" and „high PM10", located in central parts of medium to large towns.

One site is „ NO_x high" and „PM10 medium", namely Vomp an der Leiten, about 50 m from a rural motorway with very high NO_x emissions. This site is affected by high NO_x emissions from the motorway and moderate PM10 emissions (due to low emission factors on motorways for PM10).

Table 53: Comparison of classification results (level 2) of the Austrian AQ monitoring sites for local road traffic emission influence for NO_x and PM10.

NO_x class	PM10 class	number of sites
low	low	124
low	medium	14
medium	medium	15
medium	high	7
high	medium	1
high	high	9

Figure 46 shows a comparison of the road traffic emission parameters for NO_x and PM10, sorted according to NO_x, for all Austrian AQ monitoring stations.

Most of the „NO_x low, PM10 medium" sites could be classified as „low" for both pollutants, if the lower boundary for PM10 was changed from 400 kg/√km.day to 500 kg/√km.day. Then 3 sites classified as „NO_x low, PM10 medium" would remain, which are urban locations in medium to larger towns. On the other hand, four „NO_x medium" sites would move to the „NO_x medium, PM10 low" class, namely those which are located near motorways, but not in their immediate vicinity.

Most of the „NO_x medium, PM10 high" sites could be moved to the „medium" class for both pollutants if the upper boundary for PM10 was changed from 1100 to 15000 kg/√km.day. Only one site (Imst), which is located at about 150 m from a motorway but immediately at a local road with high traffic volumes and high specific PM10 emissions would remain in the „NO_x medium, PM10 high" class,.

The difference in the NO_x and PM10 classifications for Vomp an der Leiten cannot be removed by changing class boundaries as this would require the lowering of the upper boundary for PM10.

It can be concluded that a harmonisation of the classification of the influence of local road traffic emissions of NO_x and PM10 can be achieved to a large extent by adjusting the class boundaries. Nevertheless, some locations with either very high NO_x and low PM10 emissions, or vice versa – due to the predominant influence of either a motorway (with high NO_x and low PM10 emissions) or a local or urban road (with low NO_x and high PM10 emissions) – will remain in different NO_x and PM10 classes in any case. We hypothesize that a traffic classification using PM2.5 instead of PM10 would not show a better agreement with the NO_x classification, because PM2.5 data in general does not show a more distinct traffic dependence than PM10.

A complete unification of NO_x and PM10 traffic classifications may be the subject of further discussions.

With respect to the uncertainties of PM10 non-exhaust emission factors, it is recommended that such a unified classification should be based on NO_x emissions.

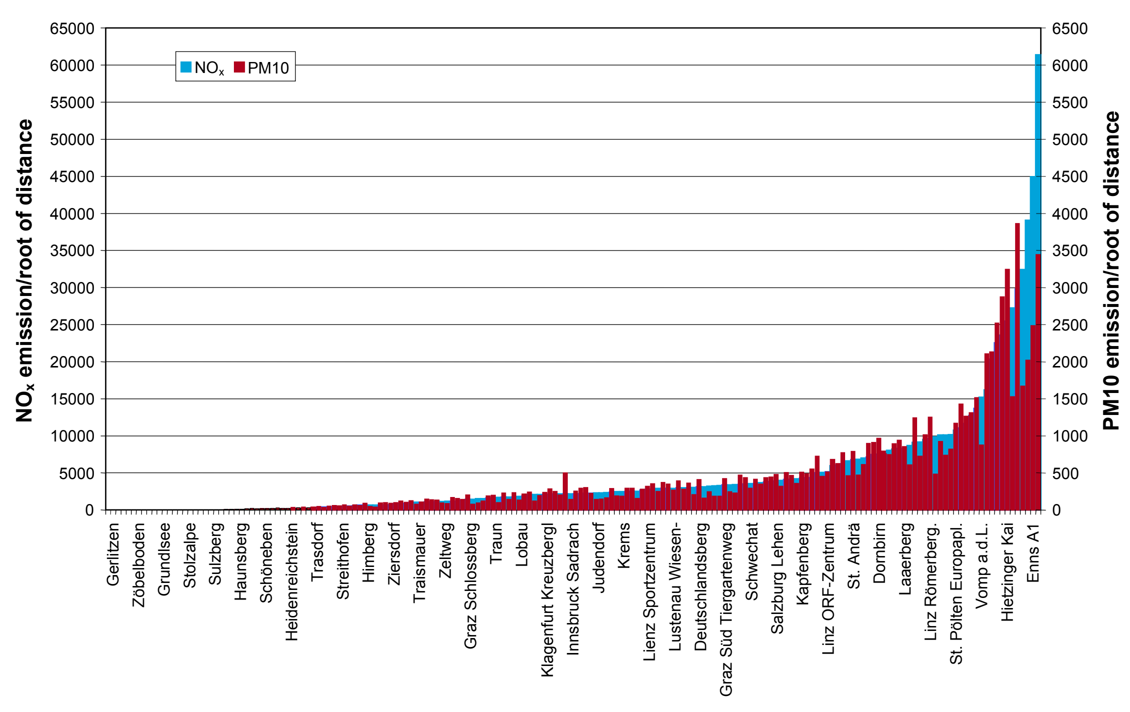

Figure 46: Comparison of the road traffic emission parameters for NO$_x$ and PM10, sorted according to NO$_x$, for all Austrian AQ monitoring stations (kg/√km.day).

A comparison of the classification according to the influence of domestic heating emissions of NO$_x$ and PM10 is given in Table 54.

Table 54: Comparison of classification results (level 2) of the Austrian AQ monitoring sites for domestic heating emission influence on NO$_x$ and PM10.

NO$_x$ class	PM10 class	number of sites
low	low	65
low	medium	25
low	high	3
Medium	low	2
medium	medium	57
medium	high	16
high	medium	4
high	high	10

Figure 47 shows a comparison of the domestic heating emissions for NO$_x$ and PM10, sorted according to NO$_x$, for all Austrian AQ monitoring stations.

A large majority of sites (132 of 183, i.e. 72%) are put into the same class for NO$_x$ and PM10: 65 sites in class „low” for both pollutants, 57 sites in class „medium” and 10 sites in class „high”.

25 sites are classified as „NO$_x$ low, PM10 medium”, located in small and medium towns. Three sites are classified as ”NO$_x$ low, PM10 high”, two of which are located in small towns and one in a location outside of Innsbruck (which ought to be attributed a (sub)urban rather than a rural emission factor for PM10).

A change of the lower class boundary for PM10 from 1 to 2 t/year would move 18 of „NO_x low, PM10 medium" stations to „low" for both pollutants, but would, on the other hand, move 29 sites from „NO_x medium, PM10 medium" to „NO_x medium, PM10 low" – which would not be useful.

The two sites classified as „NO_x medium, PM10 low" and the four sites „NO_x high, PM10 medium" are suburban sites in Wien.

16 sites in small and medium towns are classified as „NO_x medium, PM10 high".

A change of the upper boundary for PM10 from 3 to 4 t/year would move only five of these to the class „medium" for both pollutants, but would, on the other hand, also move 4 sites from „NO_x high, PM10 high" to „NO_x high, PM10 medium".

Therefore, a change of the class boundaries (either for NO_x or for PM10) would not harmonise a classification according to NO_x and PM10. The strong variation of PM10 emissions per person – compared to NO_x – and its general anti-correlation to population density mean that PM10 emissions per km² from domestic heating in small and medium towns are higher than in the suburban areas of larger towns, whereas NO_x emissions from domestic heating are more strongly correlated with the population number.

Despite the uncertainties related to the level 2 approach – population distribution and emission factors depending on population density – and due to the large variation of PM10 emissions per capita (compared to NO_x) it can be concluded that a harmonisation of the classification scheme for NO_x and PM10 domestic heating emissions seems not possible.

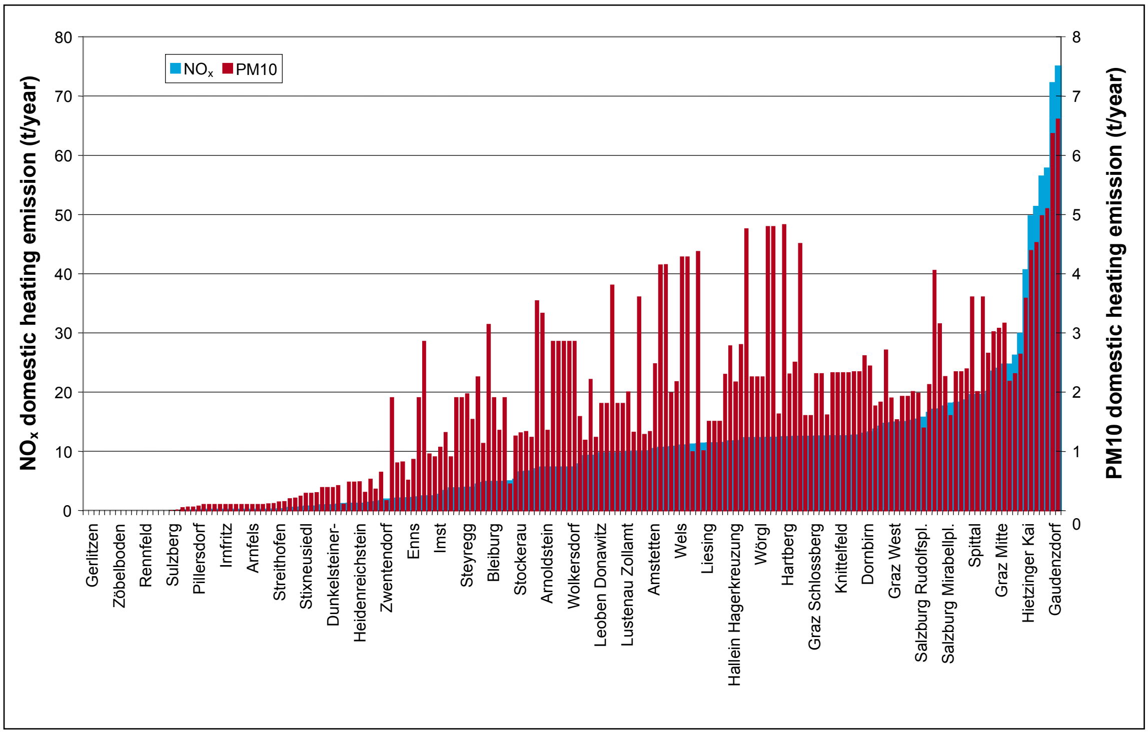

Figure 47: Comparison of domestic heating emissions (1 km radius) of NO_x and PM10, sorted according to NO_x, for all Austrian AQ monitoring stations (t/year).

6.5.13 Comparison of EoI Type of Station with NO_2 and PM10 classification

The classification for NO_x and PM10 (level 2) on the basis of the method developed in this study is compared to the „type of station" of EoI (97/101/EC) meta-data. A complete list of stations with their classification is given in Table 84 (Annex A).

There are 3 „types of station": „*traffic*", „*industrial*", and „*background*".

In Austria, the classification is performed by the government authorities of the federal provinces who run the monitoring networks, in cooperation with Umweltbundesamt. The classification is based on an assessment of the measured pollution in relation to known or estimated emissions.

The EoI classification is not related to a specific pollutant. The „traffic" classification is mainly related to NO_x (NO_2), whereas the „industrial" classification can be related to any pollutant. This means that an „industrial" site may be affected by high concentrations of one pollutant, but low („background") concentrations of other pollutants. This mismatch justifies a classification according to specific pollutants.

A comparison of the EoI station type with the classification according to local road traffic, domestic heating and industrial emissions of NO_x and PM10 presented in chapter 3.2 reveals major mismatches especially for „industrial" sites. These mismatches are mainly due to the fact that the „industrial" classification is based on any pollutant, in many cases SO_2 and heavy metals, but not NO_2 and PM10.

Arnoldstein (metallurgical plant) is an industrial site only regarding heavy metals (in former years also SO_2), but not NO_2 and PM10 (in fact, PM10 levels reflect more or less rural background).

Mannswörth is situated near the Schwechat refinery (high SO_2 emissions) which has, however, a low influence on measured NO_2 and PM10 levels.

The industrial sites St. Pölten Eybnerstraße and Lenzing measures high (although decreasing in recent years) H_2S and SO_2, but no elevated NO_2 and PM10 levels. Also, Judendorf Süd and Straßengel (pulp and paper plant) and Wien Kaiserebersdorf (refinery) are affected by high SO_2, but not by high NO_2 and PM10 levels.

Brixlegg (metallurgical plant) is classified as an industrial site with high local emissions of SO_2, PM10 and heavy metals, but it is also affected by significant road traffic emissions of NO_2 (classification „medium") and PM10, and therefore the EoI classification for NO_2 should rather be „traffic", and for PM10 either „traffic" or „industrial".

Several rural sites (Neusiedl, Trasdorf, Zwentendorf) are operated for observation of the Dürnrohr power plant, which, in fact, has very low emissions. Therefore, these sites are suitable „background" stations.

Kittsee is classified as „industrial" with respect to significant SO_2 and PM10 „transboundary" advection from Bratislava.

Several mismatches also affect the classification of „traffic" sites. In most cases the classification for EoI meta-data reflects an *overestimation* of the influence of local road traffic. This is the case especially for the „traffic sites" Eisenstadt (classification „NO_x low, PM10 medium"), Oberdrauburg (NO_x low, PM10 low), St. Veit a.d.G. (NO_x low, PM10 low), Wolfsberg (NO_x low, PM10 medium), Tulln (NO_x low, PM10 low), Braunau (NO_x low, PM10 medium), Graz Ost (NO_x low, PM10 medium), Wald am Arlberg (NO_x low, PM10 low), Wien Belgradplatz (NO_x low, PM10 medium), Wien Floridsdorf (NO_x low, PM10 low), and Wien Kendlerstraße (NO_x low, PM10 low). The most striking „error" concerns Wald am Arlberg, a rural site in the vicinity of a dual carriageway – nevertheless, the Arlberg dual carriageway has quite a moderate traffic volume and moderate emissions compared to other highways, and therefore the monitoring site Wald falls into the lowest class both for NO_x and PM10 emissions.

Some monitoring sites have been put in the EoI type of station class „background" - despite being classified as NO_x medium, PM10 medium. This concerns Brunn am Gebirge (which is influenced by the A21 motorway at some distance), Linz Kleinmünchen (suburban site in the agglomeration of Linz), and Kufstein Praxmarerstraße (A12 motorway). In these cases, the influence of major roads further away has been underestimated.

6.6 Netherlands, Rijnmond area

For the Rijnmond area – i.e. the agglomeration of Rotterdam and adjacent industrial and harbour regions (Figure 48) – emission data and model results of annual NO_2 and PM10 concentrations have been provided.

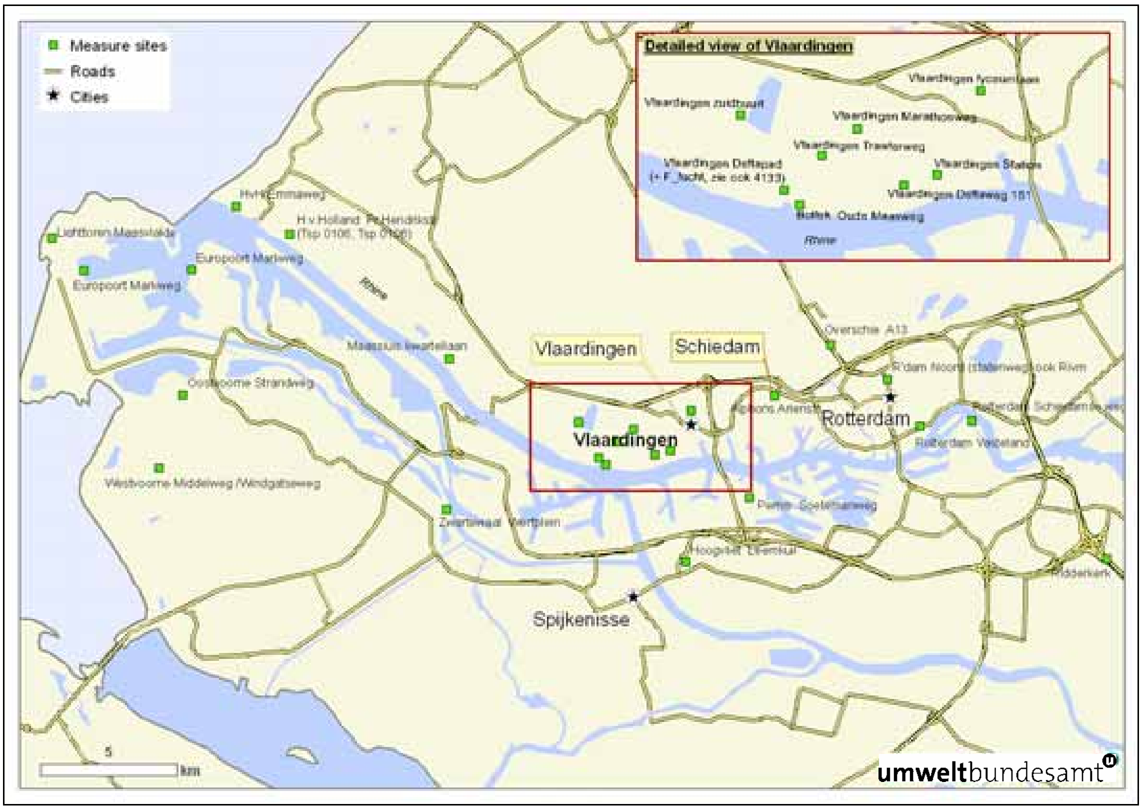

Figure 48: Monitoring sites in the Rijnmond area.

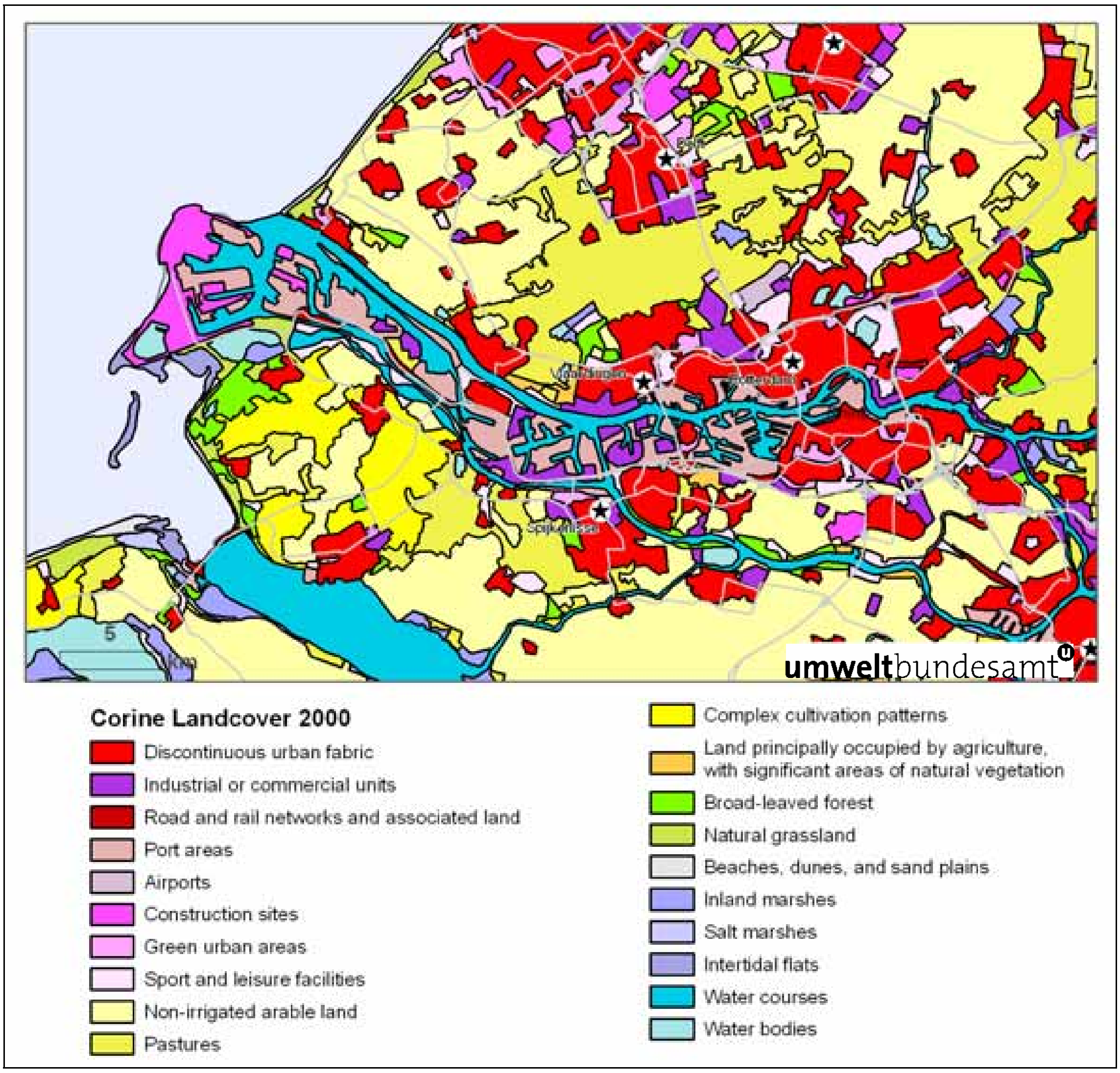

Figure 49: CORINE Landcover map of the Rijnmond area.

6.6.1 Local road traffic emissions

Out of 26 monitoring sites in the Rijnmond area (Figure 48), six sites were continuously monitoring NO_2 and/or PM10; four sites are classified as traffic related by the data provider, and the distance from the kerb as well as the traffic volume and traffic emissions for NO_x are given. The calculation of the road traffic emission parameter according to chapter 3.2.3 is shown in Table 55.

Table 55: Traffic emission parameter for traffic related sites in the Rijnmond area.

Station	Distance from kerb (m)	NO_x emission (g/m.day)	Traffic emission parameter (g/(m$^{3/2}$·day))
Overschie A13	25	238.0	47.6
Rotterdam Noord Statenweg	2	36.4	25.7
Ridderkerk	15	420.8	108.7
Vlaardingen Marathonweg	10	20.0	6.3

According to a classification scheme of three classes (chapter 6.5.4) with class boundaries at 5 and 15 g/m³/2.day, all four classes would be classified „high traffic emissions".

The traffic emission parameter for Ridderkerk by far exceeds the maximum calculated for the Austrian monitoring sites – Vomp A12 highway with 61 g/m³/2.day.

Emissions on the near-by roads are available only for four monitoring sites. Based on the emissions inventory, total road traffic emissions within a 1 km² area around the monitoring stations are available. The distribution of total NO_x emissions from road traffic suggests class boundaries at 5 t/year and 10 t/year, putting the four stations mentioned above into the class „high", and in addition the stations Rotterdam Vasteland, Schiedam Alphons Arienstraat and Vlaardingen Lyceumlaan, all characterised by Rijnmond as urban background stations (at these stations NO_2 and PM10 were not monitored).

6.6.2 Domestic heating emissions

The Rijnmond stations are classified into three classes according to domestic heating emissions within a circle of 1 km (these have been estimated from the available data, i.e. the domestic emissions of the 1 km^2 emission inventory cell in which the station was located). The results are listed in Table 56, applying the class boundaries for NO_x emissions according to chapter 6.5.4 of 9 and 20 t/year and for PM10 according to chapter 6.5.5 of 1 and 3 t/year.

Table 56: Classification of the Rijnmond stations according to domestic heating emissions of NO_x and PM10. Class boundaries for NO_x: 9 and 20 t/year, PM10: 1 and 3 t/year.

Station	**NO_x**	**PM10**
Rotterdam Vasteland	2	2
Overschie A13	1	2
Rotterdam Noord (Statenweg)	2	2
Schiedam Alphons Arienstraat	2	2
Vlaardingen Zuidbuurt	0	2
Vlaardingen Station	2	1
Maassluis Kwartellaan	1	0
Hoek van Holland Pr.Hendrikstraat	0	2
Hoogvliet Leemkuil	1	2
Pernis Soetemanweg	1	1
Europoort Markweg 1	0	0
Oostvoorne Strandweg	0	0
Westvoorne Middelweg/Windgatseweg	0	0
Zwartewaal Werfplein	0	2
Ridderkerk	0	2
Vlaardingen Deltapad 1	0	2
Europoort Markweg 2	0	0
Westvoorne Middelweg/Windgatseweg	0	0
Lichttoren Maasvlakte	0	1
Vlaardingen Deltapad 2	0	0
Hoek van Holland Emmaweg	0	0
Vlaardingen Deltaweg 161	0	2
Vlaardingen Trawlerweg	1	0
Vlaardingen Marathonweg	0	1
Vlaardingen Lyceumlaan	2	0
Rotterdam Schiedamsevest	1	2
Rotterdam Vasteland	1	0

The distribution of the domestic heating emissions of NO_x within a circle of 1 km is shown in Table 50, for PM10 in Table 51.

Applying the class boundaries derived from the distribution of emissions for the Austrian monitoring sites, the Rijnmond monitoring sites are quite equally distributed across the three classes for NO_x, whereas for the PM10 emissions, 12 of 27 sites are classified as „high".

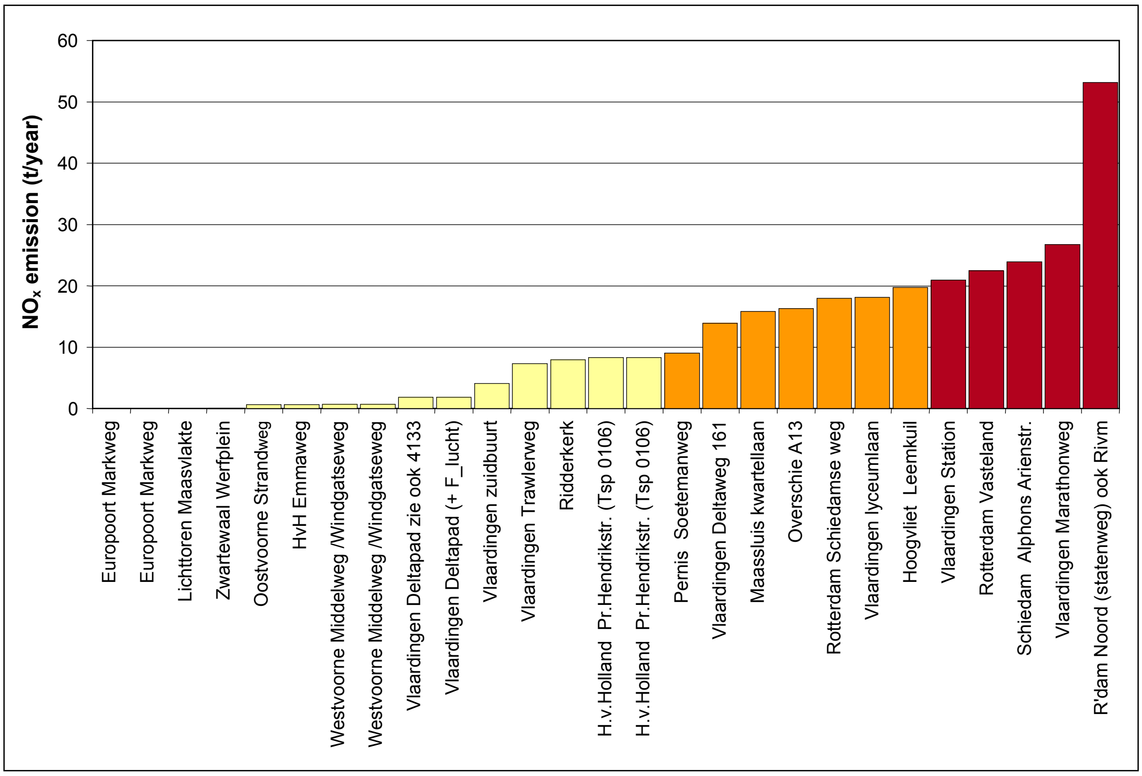

Figure 50: Distribution of domestic heating NO_x emissions within a 1 km radius around the Rijnmond monitoring stations.

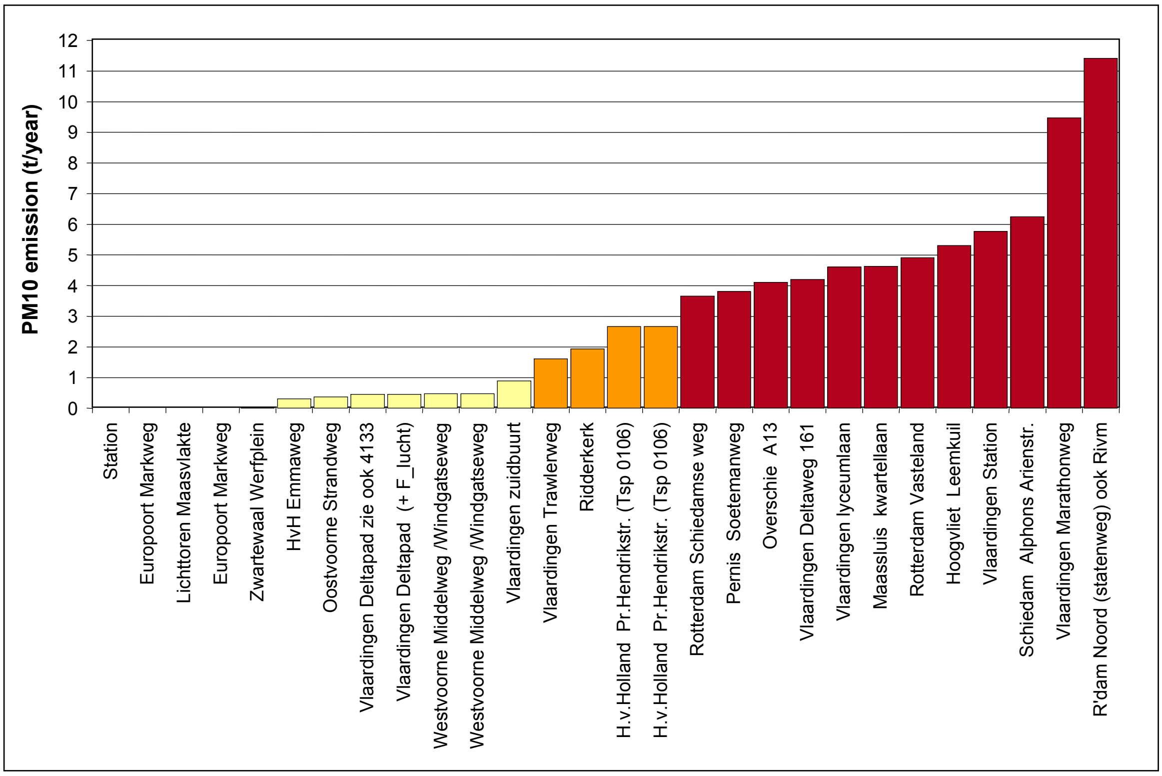

Figure 51: Distribution of domestic heating PM10 emissions within a 1 km radius around the Rijnmond monitoring stations.

Despite the impression that a distribution of domestic heating NO_x emissions around the Rijnmond stations would not suggest class boundaries of 9 and 20 t/year, these emissions fit well into the distribution of emissions around the Austrian monitoring sites (Figure 52). The distribution suggests a class boundary of at least around 20 t/year.

The distribution of the PM10 emissions within a 1 km radius around the Austrian and the Rijnmond monitoring stations (Figure 53) shows that the Dutch sites fit well into the distribution of the Austrian sites, except Vlaardingen Marathonweg and Rotterdam Noord Statenweg with extremely high PM10 emissions. Nevertheless, this distribution suggests a class boundary of around 3 t/year.

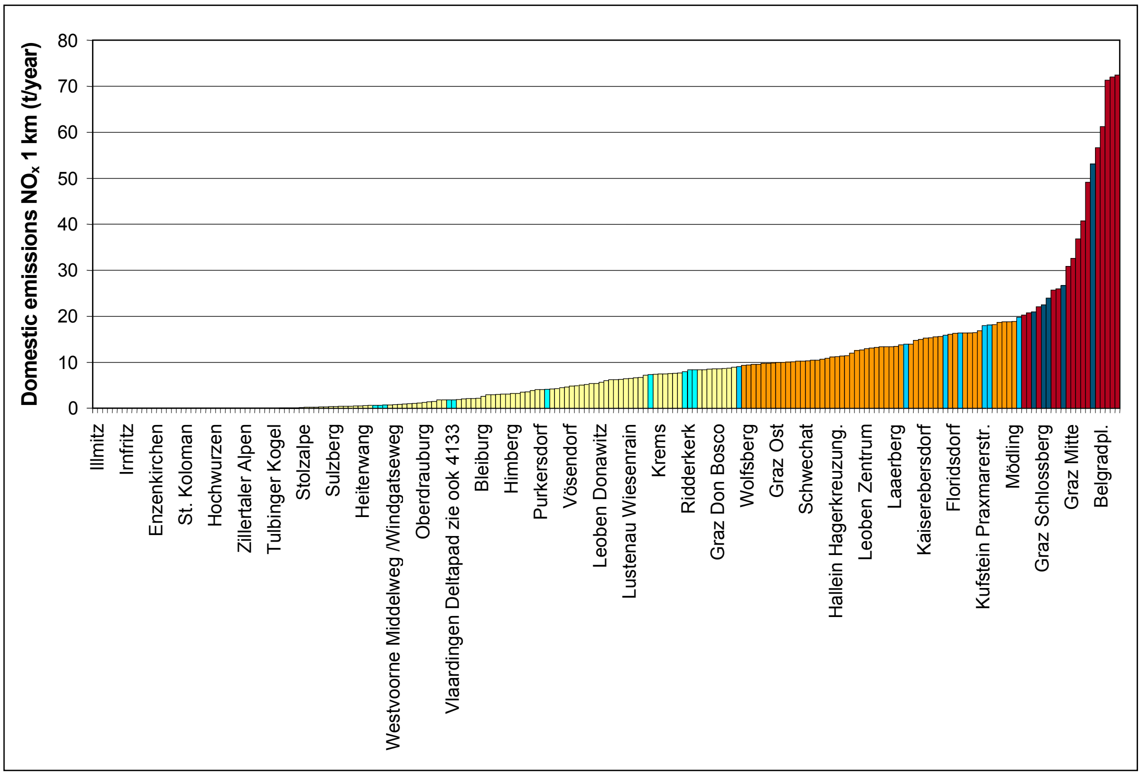

Figure 52: Combined distribution of domestic heating NO_x emissions within a 1 km radius around the Austrian (yellow – red) Rijnmond (blue) monitoring stations.

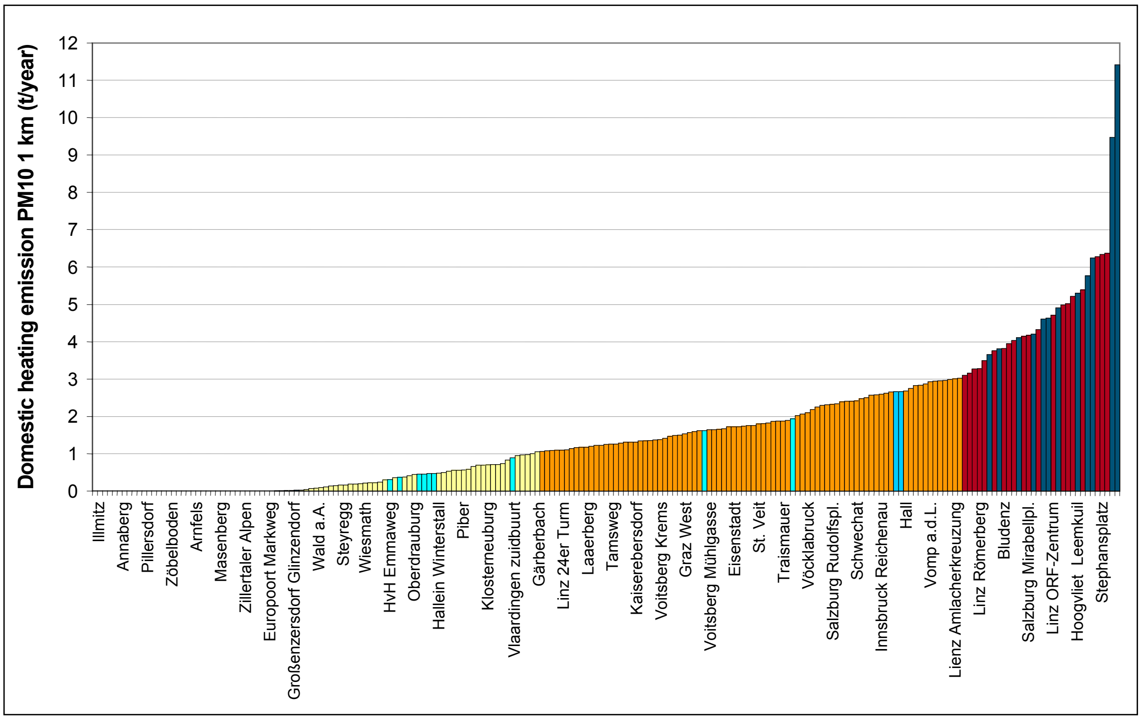

Figure 53: Combined distribution of domestic heating PM10 emissions within a 1 km radius around the Austrian (yellow – red) Rijnmond (blue) monitoring stations.

6.6.3 Industrial emissions

As stated in chapter 3.2.5, the impact of industrial emissions cannot usually be assessed simply by the total amount of emissions in the surroundings of a monitoring site, since other parameters, especially stack height, play a major role.

For the monitoring stations in the Rijnmond area, the (modelled) impact of industrial sources on NO_2 and PM10 concentrations are reported, showing quite low contributions. The maximum industrial impact on the annual mean of NO_2 is 6 µg/m³ at Vlaardingen Zuidbuurt and for PM10 8 µg/m³ at Europoort Markweg 1.

For these stations, no measured NO_2 and PM10 concentrations are reported. The total modelled NO_2 concentration in Vlaardingen Zuidbuurt is about 35 µg/m³, which would mean an industrial impact of about 15%. The total modelled PM10 concentration at Europoort Markweg 1 is about 40 µg/m³, corresponding to an industrial impact of 20%. Thus, the industrial contribution to these monitoring sites is not very high. Anyhow, the model results show much higher PM10 concentrations in the vicinity of some km southwest to Europoort Markweg 1.

According to the classification method proposed in chapter 3.2.5, emissions from ships (as well as airports) should also be included in the industrial impact. The emission data show that there are significant NO_x emissions from shipping in the near vicinity of some monitoring stations, the highest around Zwartewaal Werfplein and Rotterdam Schiedamsevest.

The total emissions from industrial sources (point + diffuse) and shipping in the vicinity of 1 km² around the air quality monitoring stations cover a range up to more than 10,000 t/year, the maximum for Europoort Markweg 1 originating from a huge point source. Emissions higher than 100 t/year can be found around Zwartewaal Werfpflein (60% from point sources, 40% from ships) and Rotterdam Schiedamsevest (85% from ships).

6.6.4 Comparison of classification results

This chapter compares the different classification results available from the Rijnmond network manager DCMR and the ones based upon the data analysed in the previous three chapters:

- Rijnmond classification
- Classification by local road traffic emissions (according to chapter 3.2.3)
- Classification by total road traffic emissions within 1 km² surroundings
- Classification by domestic heating emissions within 1 km radius (according to chapter 3.2.4)
- Classification by modelled impact of industrial sources
- Classification by total industrial and shipping emissions within 1 km² surroundings.

EoI meta-data are available only for two stations (Vlaardingen Lyceumlaan and Rotterdam Schiedamsevest), and therefore no comparison with the EoI classification is available.

Table 57 lists the different classification results, coded by „0” for „low”, „1” for „medium” and „2” for „high”.

The Rijnmond classification is not really unequivocal, since several stations are described as „industrial city background”.

All stations for which local road traffic emission data are available are classified as „high” according to the procedure in chapter 6.6.1 and are described as „motorway” or „traffic” by the Rijnmond classification.

The total NO_x emissions within surroundings of 1 km² do not completely match the Rijnmond classification. The class „high” covers all four stations classified as „high” according to local NO_x emissions from traffic, but also 3 sites described as „city/background”.

The monitoring sites classified as „high” for domestic heating emissions according to chapter 3.2.4 cover 2 sites described as „city/background” in the Rijnmond system, 2 „traffic” sites and one „industry/city” site.

The classification according to industrial emissions based on the modelled impact (which is quite low) and based on the total industrial and shipping emissions within 1 km² surroundings – and a quite deliberate class boundary selection – mismatch, as stated in chapter 6.6.3. The one site with a „medium” industrial input is described as „industry” in the Rijnmond classification system. The monitoring sites with high NO_x emissions from industry and shipping in 1 km² surroundings are classified „industry/regional”. The only site with the classification „medium” but described as „city” is Rotterdam Vasteland.

In conclusion, the two classification approaches correspond well when using the traffic emission parameters, but differences occur when using emissions within a circle of 1 km.

Table 57: Classification results for road traffic emissions, domestic heating emissions and industrial (+ shipping) emissions for NO$_x$.

Station	Dutch classification	Traffic (local)	Traffic (total 1 km²)	Domestic heating	Industry (modelled impact)	Industry + ships (1 km²)
Rotterdam Vasteland	City background		2	**2**	0	1
Overschie A13	Highway	**2**	2	**1**	0	0
Rotterdam Noord (Statenweg)	Traffic	**2**	2	**2**	0	0
Schiedam Alphons Arienstraat	City background		2	**2**	0	0
Vlaardingen Zuidbuurt	Industry		0	**0**	1	0
Vlaardingen Station	Industry, city		0	**2**	0	1
Maassluis Kwartellaan	Industry, regional		0	**1**	0	1
Hoek van Holland Pr.Hendrikstraat	Industry, regional		0	**0**	0	1
Hoogvliet Leemkuil	Industry, city background		1	**1**	0	0
Pernis Soetemanweg	Industry, city background		0	**1**	0	0
Europoort Markweg 1	Industry		0	**0**	0	1
Oostvoorne Strandweg	Regional		0	**0**	0	0
Westvoorne Middelweg/Windgatseweg	Regional		0	**0**	0	0
Zwartewaal Werfplein	Industry, regional		0	**0**	0	2
Ridderkerk	Highway	**2**	2	**0**	0	0
Vlaardingen Deltapad 1	Industry		0	**0**	0	0
Europoort Markweg 2	Industry		0	**0**	0	2
Westvoorne Middelweg/Windgatseweg	Regional		0	**0**	0	0
Lichttoren Maasvlakte	Industry, regional		0	**0**	0	1
Vlaardingen Deltapad 2	Industry		0	**0**	0	0
Hoek van Holland Emmaweg	Industry		0	**0**	0	1
Vlaardingen Deltaweg 161	Industry		0	**0**	0	0
Vlaardingen Trawlerweg	Industry		0	**1**	0	0
Vlaardingen Marathonweg	Industry		1	**0**	0	0
Vlaardingen Lyceumlaan	Traffic	**2**	2	**2**	0	0
Rotterdam Schiedamsevest	City background		2	**1**	0	0
Rotterdam Vasteland	City background		1	**1**	0	2

6.7 Further development of the classification method

The classification scheme proposed in this study was tested using data from Austria and the Netherlands. It turned out that detailed knowledge of the location of their monitoring stations as well as access to the necessary emission data is crucial for this testing. Therefore, the classification scheme should be tested in additional countries by experts such as monitoring network operators who have the required knowledge and acces to data.

The classification scheme proposed in this study can be used, as stated above, to expand the description/classification of monitoring stations – „type of station" – according to EoI. We propose that the new classification scheme should be considered in the Implementing Provisions on reporting for the revised Air Quality Directive. The main advantage of the new classification scheme is that it gives quantitative criteria (though not for all emission categories) and it is therefore uniformly applicable throughout Europe.

The „type of area" – which may be urban, suburban, and rural – could also be revised according to the proposals of this study. Chapter 3.3 presents a first approach for the classification of monitoring sites according to population distribution, related to the „type of area" in EoI, but more refined with many more classes. This classification scheme for population distribution should be tested, using population data from various countries.

In principle, the classification scheme proposed in this study is compatible with the present EoI „type of station" description, retaining the basic classes „traffic", „industrial" and „background"; the class „unknown" should be removed. The main technical change concerns the shift of classification from the station level to the pollutant level („measurement configuration" in the Data Exchange Module).

At present, the station description/classification according to EoI is static, without reference to a certain year. Updates are not documented, and neither is the status in earlier times. Any classification can, however, change due to changes in the emissions on which it is based, e.g. by constructing new roads or by abatement measures at certain industrial plants.

Further developments of reporting on meta-information should therefore include

- giving the reference year of the station description/classification,
- updating (periodically) the station description/classification,

7 VALIDATION OF THE ASSESSMENT OF REPRESENTATIVENESS

7.1 Validation method

The procedure to test the **method for the assessment of representativeness** is based on available measurement data, modelling data, and surrogate data for the estimation of concentrations, emissions and dispersion situation.

The proposed method for the assessment to delimitate the area of representativeness is applied to selected monitoring stations. Where measurement or model data are available for this area, it is checked if these AQ data fit the criteria of the definition of representativeness (i.e. if measured concentrations are within the threshold values *and* if the stations are similar in terms of sources and dispersion situation).

Further it is investigated if

1. areas of representativeness largely overlap;
2. there remain large areas which are covered by no representative monitoring station.

In the first case it is assessed and discussed if

- the monitoring network is in fact largely redundant;
- the criteria for „similarity" are not strict enough.

Also if areas remain which are covered by no representative monitoring site, the criteria for similarity are evaluated.

In addition, the validation also covers the question if the annual percentile of PM10 (daily mean values) and ozone (daily maximum 8-hourly mean values) are appropriate to represent the maximum allowed number of exceedances according to EU AQ standards.

7.2 Austria

7.2.1 Input data

The method to assess the representativeness of AQ monitoring stations is tested and validated using a combination of data sets, which are summarised in Table 58. For different regions, different input data are available.

Table 58: Input data used for test and validation of the method for assessing the representativeness of monitoring sites in Austria.

Region	AQ data	Emissions	Local dispersion situation
North-eastern Austria (around Wien)	Routine monitoring network	Emission inventory in Wien Outside Wien: Road network – Teleatlas Domestic heating from population distribution Industrial plants (UMWELTBUNDESAMT 2006)	Building structure map in Wien Assessment based on CLC and 1:50.000 map outside Wien
Klagenfurt	Model data	Emission inventory	
Inn valley, Tirol	Routine monitoring network + measurement campaign by diffuse samplers	various data sources compiled for studies on NO_2 and PM10 LV exceedances (UMWELTBUNDESAMT 2004b, 2005b)	

As routine monitoring data, measurements from 182 Austrian AQ monitoring sites (Figure 54) for NO_2, NO_x, PM10 and ozone were available:

- NO_2, NO_x and ozone values for the years 2002, 2003 and 2004.
- PM10 data for the years 2002, 2003, 2004 and 2005 (the year 2005 was chosen in order to increase the availability of PM10 monitoring stations, since several stations started measurements only in recent years).

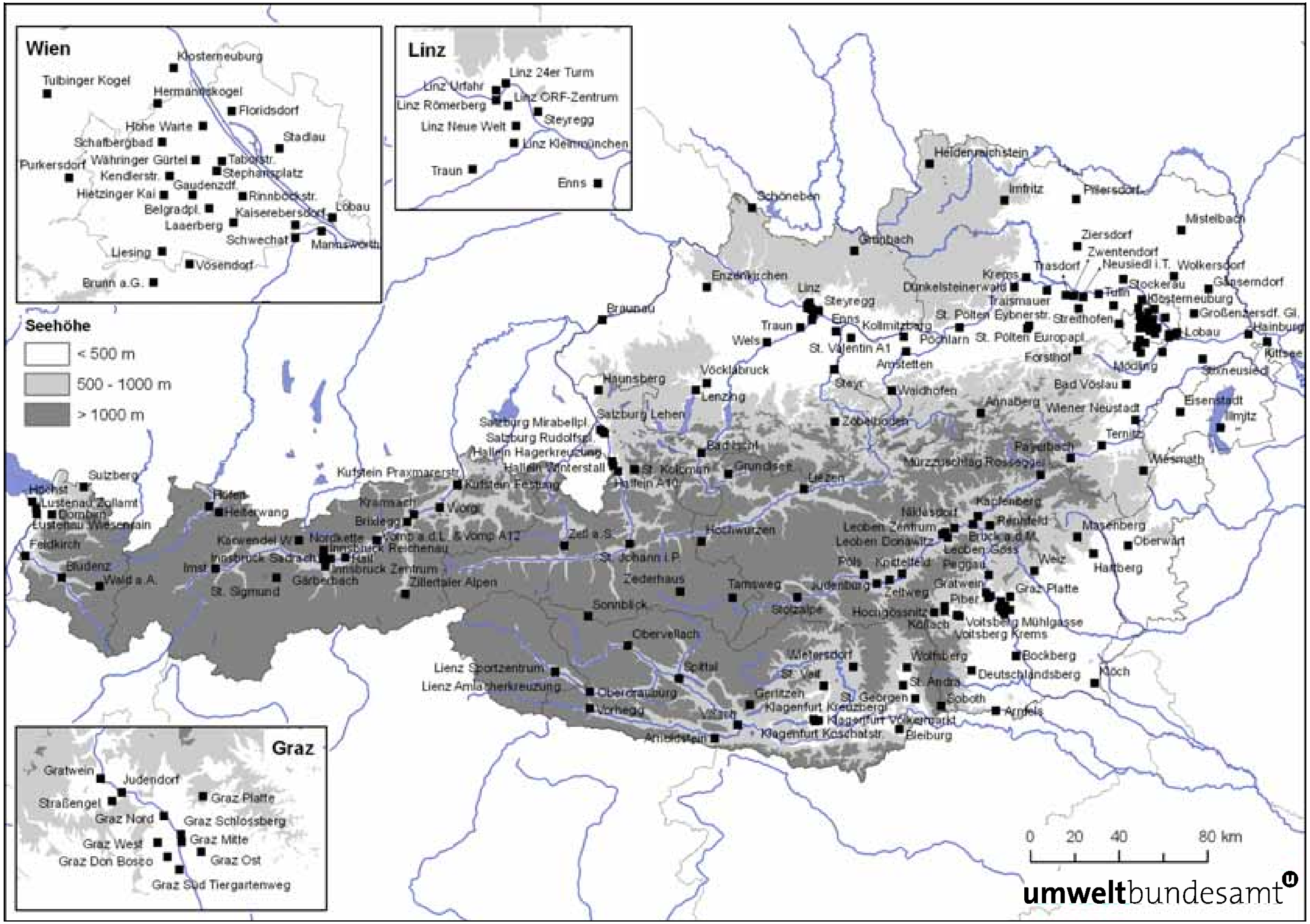

Figure 54: Air quality monitoring sites in Austria.

7.2.2 North-eastern Austria

7.2.2.1 NO_2 and PM10, analysis of routine monitoring data

The NO_2, PM10 and ozone monitoring sites available in north-eastern Austria, the region around the agglomeration Wien, can be seen in Figure 55.

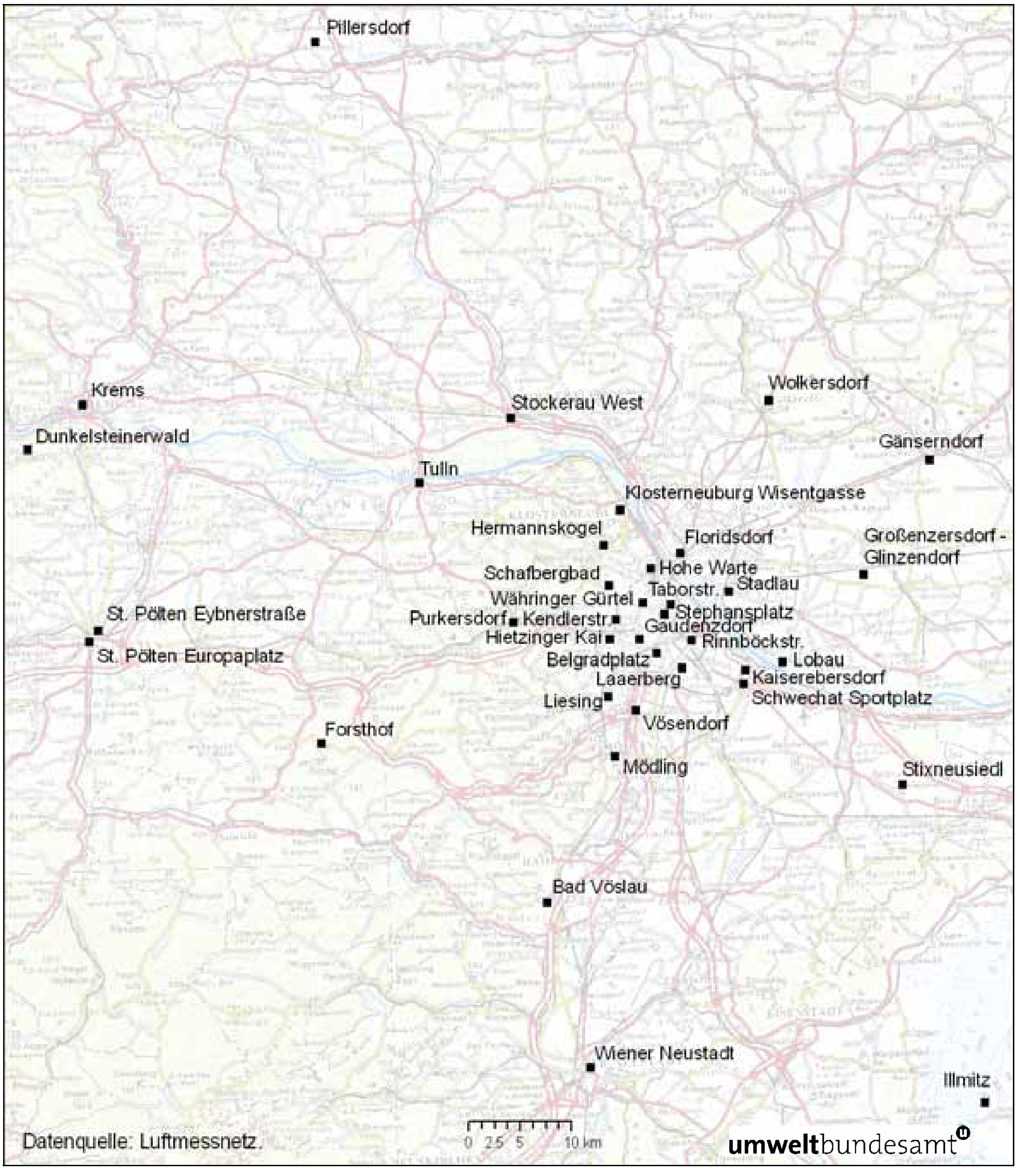

Figure 55: Air quality monitoring sites in north-eastern Austria.

In the following, various monitoring sites are looked at in detail. It is discussed which other monitoring stations fulfil the criteria for representativeness (chapter 4.2) with respect to these sites. Lists of the corresponding monitoring stations can be found in the Appendix (Table 85 to Table 90).

Illmitz, rural background: The NO_2 annual mean in Illmitz in all years 2002 to 2004 was 9 µg/m³. The annual PM10 mean values for 2003 to 2005 were 31, 24 and 27 µg/m³, respectively, the annual 90.2 percentiles were 61, 47 and 53 µg/m³, respectively.

As a rural EMEP background site, Illmitz is in the lowest traffic, domestic heating and industrial emission class (chapter 3.2).

Table 85 (Annex) lists those other NO_2 and PM10 monitoring stations in Austria which fulfil the representativeness criteria in comparison to Illmitz. The primary selection criterion is the concentration range of ±5 µg/m³ for the annual mean NO_2 concentration 2002, 2003 and 2004, ±5 µg/m³ for the annual mean PM10 concentration and ±8 µg/m³ for the annual 90.2 percentile of the PM10 daily mean values for the years 2003, 2004 and 2005. All monitoring sites listed in column 1 for the NO_2 concentration criterion fit into the same (lowest) emission class both for traffic, domestic heating and industrial emissions. The monitoring sites which fulfil all criteria and which are situated within a radius of 100 km around Illmitz are printed in bold.

The monitoring sites fitting into the concentration criterion for NO_2 are rural sites in various locations spread throughout Austria.

On the contrary, the monitoring sites fitting into the concentration criteria for PM10 cover various types of monitoring sites

- in rural areas in north-eastern Austria
- background as well as traffic sites in small towns in alpine valley
- background sites in the agglomeration Wien.

This clearly shows that due to the high regional background concentration which affects Illmitz, PM10 levels in this rural area are similar to urban and even traffic sites in alpine valleys.

The area of representativeness of Illmitz for NO_2 has to fulfil the criteria for the concentration and the local and regional dispersion situation. The large scale topographic region covers the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain – and parts of north-western Hungary.

Applying the criterion of atmospheric transport and conversion to a maximum distance of 100 km, a wider area than the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain would be covered (see Figure 56).

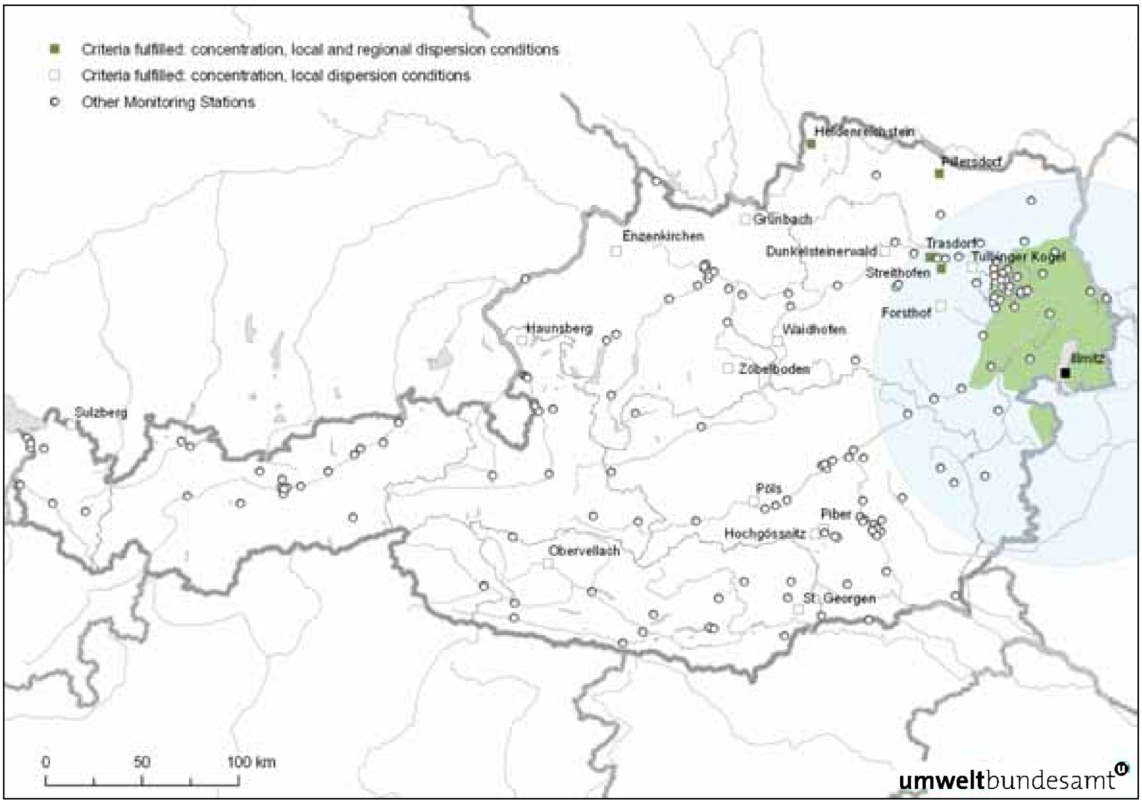

Figure 56: Monitoring sites which fulfil the criteria for the NO2 concentration and the local and regional dispersion situation related to Illmitz (within Austria). Green: Large-scale topographic region „Pannonian Plain", which covers the northern Burgenland province, „Wiener Becken" basin and Marchfeld plain within Austria. Blue: radius of 100 km around Illmitz.

The area of representativeness of Illmitz for PM10 has to fulfil the criteria for the concentration, emissions, and the local and regional dispersion situation. The large scale topographic region covers the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain – and parts of north-western Hungary. *This area includes the monitoring station Glinzendorf*.

Applying the criterion of atmospheric transport and conversion to a maximum distance of 100 km, a wider area than the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain would be covered. *This area would include the monitoring sites Großenzersdorf and Glinzendorf.*

Eisenstadt, small town: The NO_2 annual mean in Eisenstadt in all years 2002 to 2004 is 20 µg/m³. The annual PM10 mean values[24] for 2003 to 2005 are 33, 25 and 30 µg/m³, respectively, and the annual 90.2 percentiles are 58, 47 and 57 µg/m³, respectively.

Eisenstadt is in the lowest emission class for traffic NO_x emissions and industrial NO_x and PM10 emissions and in the „medium class" for traffic PM10 emissions and NO_x and PM10[25] emissions from domestic heating.

Table 86 (Annex) lists those other NO_2 and PM10 monitoring stations in Austria which fulfil the representativeness criteria in comparison to Eisenstadt. The primary selection criterion is the concentration range of ±5 µg/m³ for the annual mean NO_2 concentration in 2002, 2003 and

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[24] possible underestimation due to too low correction factor.

[25] possible overestimation due to high emissions per capita.

2004, ±5 µg/m³ for the annual mean PM10 concentration and ±8 µg/m³ for the annual 90.2 percentile of the PM10 daily mean values for the years 2003, 2004 and 2005. The monitoring sites which fulfil all criteria and which are situated within a radius of 100 km around Illmitz are printed in bold.

The concentration criterion for NO_2 links Eisenstadt with a multitude of other background sites in small to medium towns throughout Austria, many of them falling into the same emission classes, but there are also several sites in the „low" class for domestic heating emissions.

Almost none of the other sites that fulfil the NO_2 concentration criterion also fit the PM10 concentration criterion; the quite high PM10 concentration in Eisenstadt (due to a high regional background level) links Eisenstadt with several urban and industrial sites, amongst them some sites in the agglomerations Wien and Linz.

The area of representativeness of Eisenstadt for NO_2 has to fulfil the criteria for concentrations, emissions, and local and regional dispersion situation. The large-scale topographic region covers the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain – and parts of north-western Hungary. *This area includes no other NO_2 monitoring station*.

Applying the criterion of atmospheric transport and conversion to a maximum distance of 100 km, a wider area than the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain would be covered. *This area would include the monitoring site Klosterneuburg* (Figure 57).

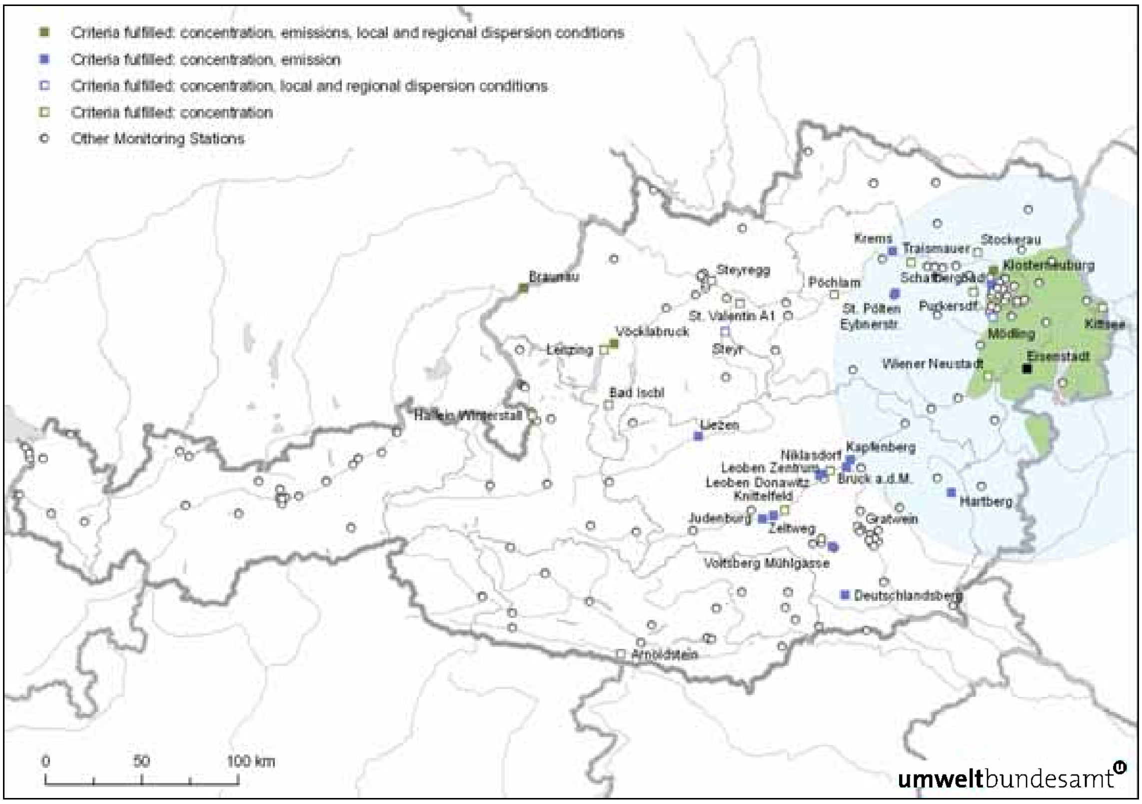

Figure 57: Monitoring sites which fulfil the criteria for the NO_2 concentration and the local and regional dispersion situation related to Eisenstadt (within Austria). Green: Large-scale topographic region „Pannonian Plain", which covers the northern Burgenland province, „Wiener Becken" basin and Marchfeld plain within Austria. Blue: 100 km radius around Eisenstadt.

The area of representativeness of Eisenstadt for PM10 has to fulfil the criteria for the concentration, emissions, and the local and regional dispersion situation. The large-scale topographic region covers the northern Burgenland province, the „Wiener Becken" basin and Marchfeld plain – and parts of north-western Hungary. *This area includes the monitoring station Wien Laaerberg*.

Applying the criterion of atmospheric transport and conversion to a maximum distance of 100 km, a wider area than the northern Burgenland province, the „Wiener Becken" basin and Marchfeld plain would be covered. *This area would include the monitoring station Wien Laaerberg.*

St. Pölten Eybnerstraße, medium-sized town, background: NO_2 annual mean values in St. Pölten Eybnerstraße in the years 2002 to 2004 were 24, 25 and 24 µg/m³, respectively. The annual PM10 mean values for 2003 to 2005 were 26, 26 and 29 µg/m³, respectively, and the annual 90.2 percentiles were 44, 43 and 52 µg/m³, respectively.[24]

St. Pölten Eybnerstraße is in the lowest emission class for road traffic NO_x and PM10 emissions and industrial NO_x and PM10 emissions, in the „medium" class for domestic heating NO_x emissions and the „high class" for PM10 emissions from domestic heating.

Table 87 (Annex) lists those other NO_2 and PM10 monitoring stations in Austria which fulfil the representativeness criteria in comparison to St. Pölten Eybnerstraße. The primary selection criterion is the concentration range of ±5 µg/m³ for the annual mean NO_2 concentration in 2002, 2003 and 2004, ±5 µg/m³ for the annual mean PM10 concentration and ±8 µg/m³ for the annual 90.2 percentile of the PM10 daily mean values for the years 2003, 2004 and 2005.

At St. Pölten Eybnerstraße concentrations „similar" to several other background sites in small and medium-sized towns in Austria, but also suburban sites in Wien are measured. Several of these sites, however, are affected by higher emissions from domestic heating.

The concentration criterion is fulfilled at several rural and small town sites in north-eastern Austria, which, however, are affected by lower PM10 emissions from domestic heating. These discrepancies may be due to variations in long-range transport, which is more noticeable in the eastern parts of Niederösterreich (Lower Austria), and also to uncertainties regarding the PM10 correction factors. The concentration criterion links St. Pölten Eybnerstraße also with highly traffic influenced sites in the province of Tirol (Tyrol) as well as with urban sites in the agglomeration Wien.

The area of representativeness of St. Pölten Eybnerstraße for NO_2 has to fulfil the criteria for the concentrations, emissions, and local and regional dispersion situation. The large-scale topographic region covers the Alpenvorland (alpine foothills), which also include parts of Bayern (Bavaria). *This area includes the monitoring station Krems*.

Applying the criterion of atmospheric transport and conversion to a maximum distance of 100 km, a wider area than the Alpenvorland would be covered. *This area would include the monitoring site Krems.*

The area of representativeness of St. Pölten Eybnerstraße for PM10 has to fulfil the criteria for the concentrations, emissions, and local and regional dispersion situation. The large scale topographic region covers the Alpenvorland (alpine foothills), which also includes parts of Bayern (Bavaria). *This area includes no other PM10 monitoring station*.

Applying the criterion of atmospheric transport and conversion to a maximum distance of 100 km, a wider area than the Alpenvorland would be covered. *This area would include the monitoring station Mistelbach.*

Vösendorf, with medium traffic influence (150 m from the A2 motorway), just outside the agglomeration Wien. The NO_2 annual mean values in St. Pölten in the years 2002 to 2004 were 33, 33 and 27 µg/m³, respectively. The annual PM10 mean values[24] for 2003 to 2005 were 30, 33 and 39 µg/m³, respectively, and the annual 90.2 percentiles were 49, 53 and 63 µg/m³, respectively. Whereas the NO_2 level decereased in 2005, the PM10 level strongly increased.

Table 59 lists those other NO_2 and PM10 monitoring stations in Austria which fulfil the concentration criteria in comparison to Vösendorf. The primary selection criteria is the concentration range of ±5 µg/m³ for the annual mean NO_2 concentration 2002, 2003 and 2004, ±5 µg/m³ for the annual mean PM10 concentration and ±8 µg/m³ for the annual 90.2 percentile of the PM10 daily mean values for the years 2003, 2004 and 2005.

Several monitoring sites in Austria fulfil the concentration criterion for NO_2. Nevertheless, none of these is in the same emission class – most of these sites are urban background locations (many of them in the agglomeration Wien) with higher emissions from domestic heating and lower emissions from road traffic. Vösendorf is the only site in the province of Niederösterreich in the ”medium” NO_x emission class.

No other site fulfils the concentration criterion for PM10.

Table 59: Representativeness criteria fulfilled for Vösendorf for NO_2.

Concentration within range in all years	**Emission**	**Dispersion**	
	NO_x	**Local**	**Regional**
Klagenfurt Koschatstr.			
Villach			
Linz Kleinmünchen			ok
Linz ORF-Zentrum			ok
Wels			ok
Salzburg Lehen			
Graz West			
Leoben Göss			
Kufstein			
Bludenz			
Wald a.A.		ok	
Wien Floridsdorf			ok
Wien Kaiserebersdorf			ok
Wien Kendlerstr.			ok
Wien Laaerberg		ok	ok
Wien Stadlau			ok
Wien Stephansplatz			ok
Wien Währinger Gürtel			ok

Wien Taborstraße: central urban site in the agglomeration of Wien with a high traffic influence in a street canyon. Classified as „medium” both for NO_x and PM10 emissions from road traffic, and „high” from domestic heating.

The annual mean NO_2 values for the years 2002 to 2004 are 43, 44 and 41 µg/m³. PM10 measurements started in 2006. Data are not available.

There are few stations in Austria which fulfil the concentration criterion, and they are listed in Table 60. Several stations with a „medium traffic" influence in quite different locations fulfil the concentration criterion, most of them in alpine basins and valleys where adverse dispersion situation cause high NO_2 levels despite moderate emissions.

One other site in Vienna fits the concentration and emission criteria, but Rinnböckstraße is located in a suburban area with a detached building structure; its predominant NO_2 source is not the nearby minor road, but the A23 motorway some 120 m away. This means that no other site is situated within the representativeness area of Wien Taborstraße.

Table 60: Representativeness criteria fulfilled for Wien Taborstraße for NO_2.

Concentration within range in all years	Traffic emission	Dispersion	
		Local	Regional
St. Pölten Europaplatz	ok	detached	ok
Graz Mitte	low	ok	basin
Graz Süd	low	detached	basin
Hall i.T.	ok	detached	valley
Höchst	ok	detached	valley
Lustenau Zollamt	ok	detached	valley
Wien Rinnböckstraße	ok	detached	ok

Wien Hietzinger Kai: Urban location with heavy local traffic in the agglomeration Wien. The site is classified as „high traffic", „high domestic heating" and „low industrial" both for NO_2 and PM10. The annual mean NO_2 values are 57, 64 and 68 µg/m³ for the years 2002 to 2004, respectively.

There is only one other monitoring site in Austria fulfilling the concentration criterion, namely Vomp A12 at the Inntal motorway in an alpine valley, the site with the highest local traffic emissions.

The Vomp site clearly does not fulfil any of the criteria related to the dispersion situation – as it is located in an alpine valley with free air flow around the site, whereas Hietzinger Kai is situated at a half-street-canyon in the agglomeration Wien.

Wien Belgradplatz: Urban background site in densely built-up area. The annual mean NO_2 values are 37, 37 and 33 µg/m³ for the years 2002 to 2004, respectively, the PM10 annual mean values for the years 2003 to 2005 are 35, 27 and 32 µg/m³.

The classification according to local road traffic is „low" for NO_2 and „medium" for PM10. The classification according to domestic heating is „high" both for NO_2 and PM10, according to industrial emissions „low" for both pollutants. The local building structure is „detached", the regional location „plain".

The area of representativeness of Wien Belgradplatz for NO_2 covers – fulfilling all criteria – the monitoring stations Wien Floridsdorf and Wien Währinger Gürtel (Table 88, Annex).

The area of representativeness of Wien Belgradplatz for PM10 covers – fulfilling all criteria – the monitoring station Wien Gaudenzdorf.

Wien Gaudenzdorf is affected by higher NO_x emissions from local road traffic („medium" class) than Belgradplatz, Floridsdorf and Währinger Gürtel, whereas for PM10, Belgradplatz and Gaudenzdorf are classified „medium" for local road traffic emissions.

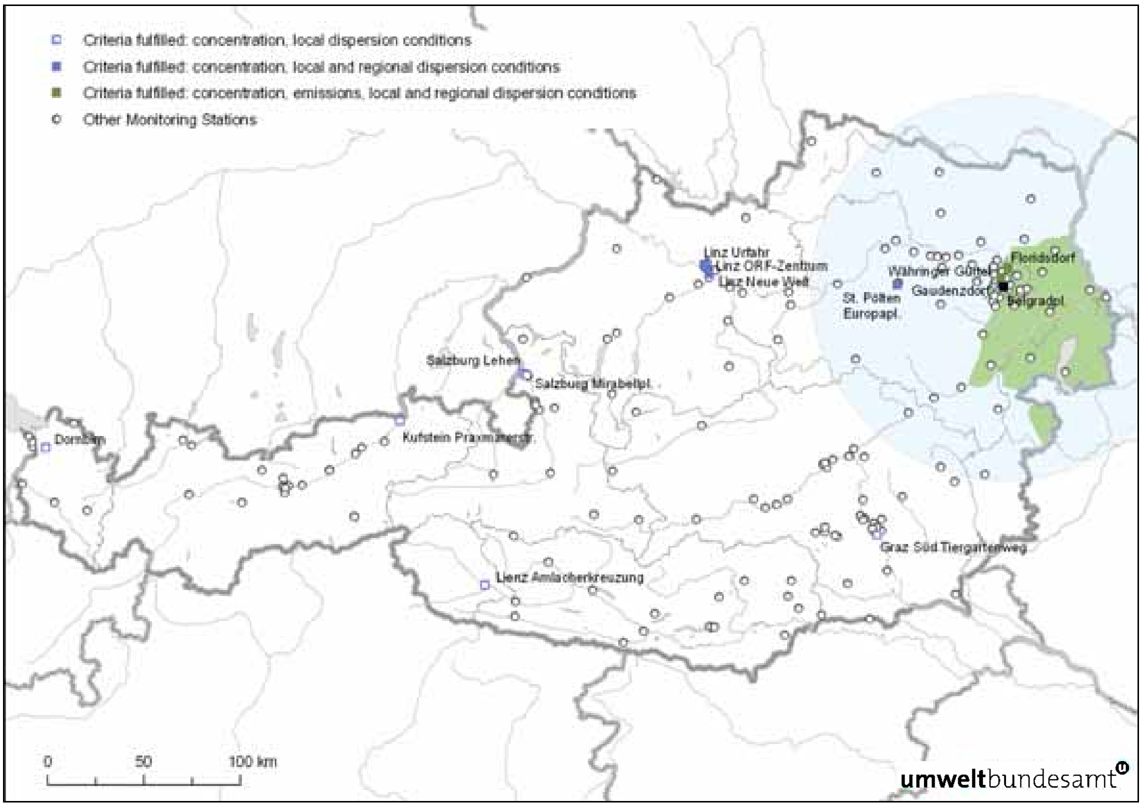

Figure 58: Monitoring sites which fulfil the criteria for NO_2 concentrations and local and regional dispersion situation related to Wien Belgradplatz.

It can be concluded that for monitoring sites with low NO_2 concentrations, the concentration criterion and the emission criteria largely coincide. For monitoring sites with medium NO_2 concentrations, similar concentrations can coincide with various combinations of emissions and dispersion situation.

7.2.3 Comparison of concentration criteria for PM10

As stated in chapter 4.3.3, there is a quite close correlation between the average PM10 concentration and the 90.4 percentile of the daily mean values. However, it has to be noted that this relationship may change, e.g. as a consequence of short-term actions which affect daily mean values more strongly than the long-term average.

The criteria for representativeness of PM10 monitoring sites given in chapter 4.3.3 are based both upon the annual mean and the 90.4 percentile of the daily mean values, but it was discussed whether only one of these parameters should be used. The annual mean would be the preferred parameter, as it is easier to calculate and a statistically more robust value.

For all monitoring sites whose representativeness has been checked in the previous chapter 7.2.2 – and which fulfil also the criteria for emissions and dispersion situation – both concentration criteria give the same area of representativeness. From this it may be concluded that it is sufficient to use only one PM10 concentration parameter.

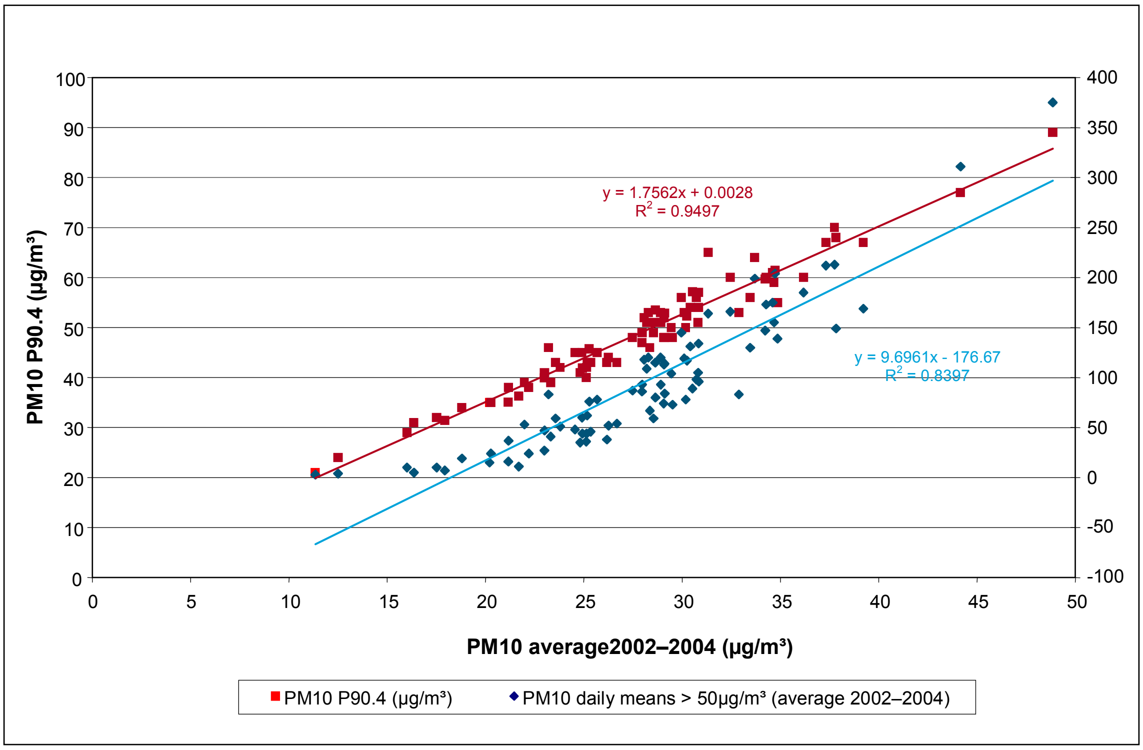

Figure 59: Relation of the average PM10 concentration (2002–2004) to the number of days with daily means above 50 µg/m³ and the 90.4 percentile at all Austrian PM10 monitoring stations.

7.2.4 Representativeness of monitoring stations for NO_x (ecosystems & vegetation)

The representativeness of NO_x monitoring sites is checked for rural sites which are representative of ecosystems and vegetation according to the siting criteria of Directive 1999/30/EC.

Table 61 lists those other NO_x monitoring stations in Austria which fulfil the representativeness criteria in comparison to **Illmitz**. The primary selection criterion is the concentration range of ±5 µg/m³ (NO_2) for the annual mean NO_x concentrationof 2002, 2003 and 2004. The annual mean NO_x concentration in Illmitz varies between 10 and 11 µg/m³ (as NO_2).

All stations fulfilling the concentration criterion fall into the lowest emission class for NO_x.

These sites represent remote rural locations in plain and hilly terrain, with some of them situated in slightly elevated or hilly regions (Pillersdorf, Heidenreichstein), and most of them in hilly alpine locations.

Table 61: Representativeness criteria fulfilled for Illmitz for NO_x.

Concentration within range in all years	Local and regiuonal dispersion situation
Forsthof	
Heidenreichstein	ok
Payerbach	
Pillersdorf	ok
Tulbinger Kogel	
Waidhofen an der Ybbs	
Grünbach	
Haunsberg	
St. Koloman	
Hochgössnitz	
Piber	
Sulzberg	

The area of representativeness for NO_x at Illmitz has to fulfil the criteria for concentration, emissions, and the local and regional dispersion situation. The large scale topographic region covers the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain, which includes also parts of Hungary. *This area includes no other NO_x monitoring station*. This would also be the case when applying the criterion of atmospheric transport and conversion to a maximum distance of 100 km (see Figure 60).

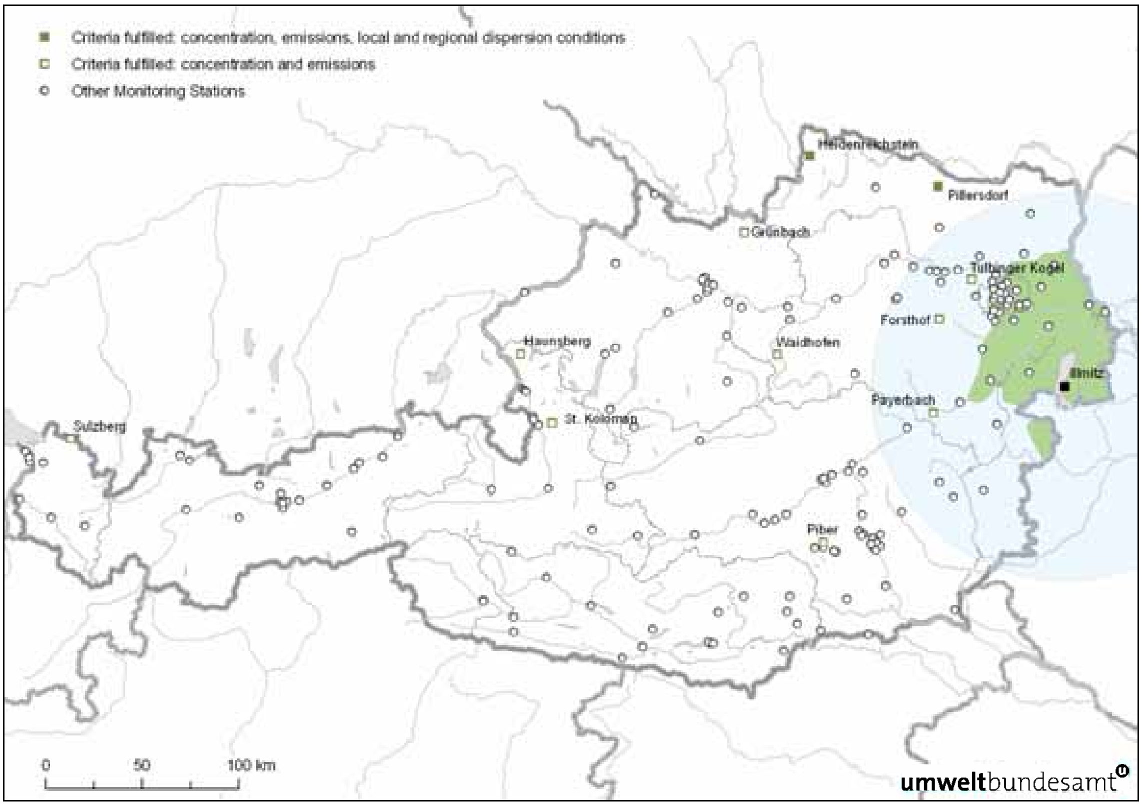

Figure 60: Monitoring sites which fulfil the criteria for NO_x concentrations and local and regional dispersion situation related to Illmitz.

7.2.5 Ozone

The criteria for the representativeness of ozone monitoring sites are:

- annual 93.2 percentile within a range of ±9 µg/m³ for the years 2002, 2003 and 2004
- same NO_x emission class (classes „medium” and „high” are merged)
- same ozone formation class (high/low)
- same type of exposure (flat/exposed)
- same regional dispersion situation

These criteria have been checked for **Illmitz**. The monitoring sites which fulfil the concentration criterion are listed in Table 89 (Annex).

All monitoring sites which fulfil the concentration criterion except Vösendorf are in the „low” traffic emission class for NO_x.

The concentration criterion covers mostly the highly polluted ozone monitoring sites – regarding the 8-hour mean value – except some sites with the highest 93.2 percentiles in south-eastern Austria. The concentration criterion includes all high alpine sites with high constant long-term ozone concentrations, which clearly shows that monitoring sites in completely different locations can record similar 93.2 percentiles of the daily maximum 8-hour mean values.

The concentration criterion, nevertheless, covers most of the rural and small-town sites in north-eastern and northern Austria, most of which also fit into the criteria for exposure (flat terrain) and ozone formation (in the plume of Wien).

The area of representativeness of Illmitz, related to the ozone 8-hour mean values, therefore covers rural and small-town areas in north-eastern Austria in flat terrain which are affected by ozone formation in the plume of Wien.

The area of representativeness of Illmitz for ozone has to fulfil the criteria for concentrations, emissions, and local and regional dispersion situation. The large-scale topographic region covers the northern Burgenland province, the „Wiener Becken” basin and the Marchfeld plain, which includes also parts of Hungary. *This area includes a multitude of monitoring stations: Kittsee, Bad Vöslau, Gänserndorf, Glinzendorf, Hainburg, Himberg, Mödling, Schwechat, Stixneusiedl, Wiener Neustadt and Wien Lobau.*

When applying a radius of 100 km around Illmitz instead of using the large-scale topographic region, the monitoring site Mistelbach would also be included.

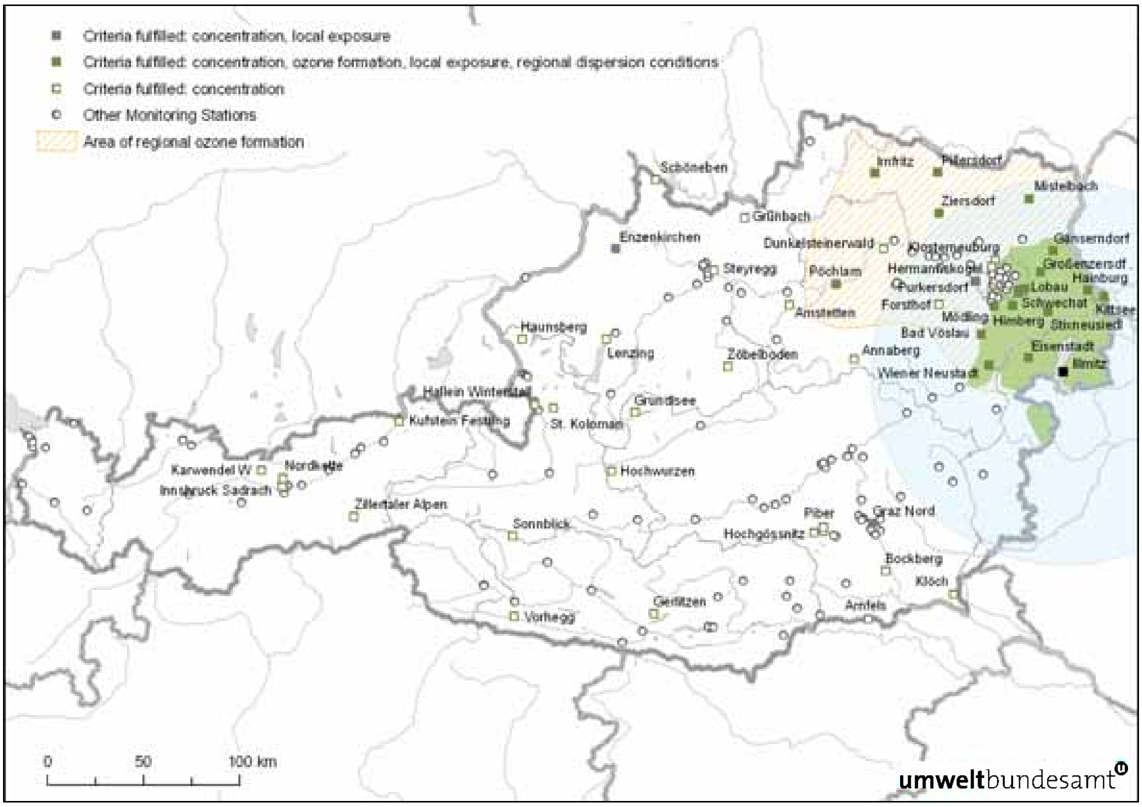

Figure 61: Monitoring stations within the area of representativeness of Illmitz for ozone, different approaches.

Table 90 (Annex) lists the monitoring stations fulfilling the representativeness criteria for **Annaberg**. Annaberg is a remote, exposed site located in hilly terrain in the north-eastern part of the Alps in southern Niederösterreich (province of Lower Austria). It is not affected by the increased regional ozone formation in the plume of Wien.

Table 90 (Annex) covers many ozone monitoring sites in north-eastern Austria in flat terrain affected by the ozone formation in the plume of Wien, and also several monitoring sites distributed over all of Austria in elevated hilly or high alpine terrain, up to the highest site Sonnblick (3106 m).

The area of representativeness of Annaberg for Ozone has to fulfil the criteria for concentrations, emissions, and the local and regional dispersion situation. The large-scale topographic region covers the northern Alps, which would also include parts of southern Germany, Switzerland and south-eastern France. *This area includes (within Austria) the monitoring stations Waidhofen, Zöbelboden, Haunsberg, St. Koloman, Grundlsee and Innsbruck Sadrach (*Figure 62*).*

Applying a radius of 100 km around Annaberg would mean to include, on the one hand, non-alpine areas in the northern part of Austria (Bohemian Massif) and parts of the Southern Alps, but exclude most of the alpine arc which covers an area of almost 1000 km to the west. *The area of representativeness then would then include the monitoring stations Waidhofen, Grünbach, Steyregg, Zöbelboden and Hochgössnitz.*

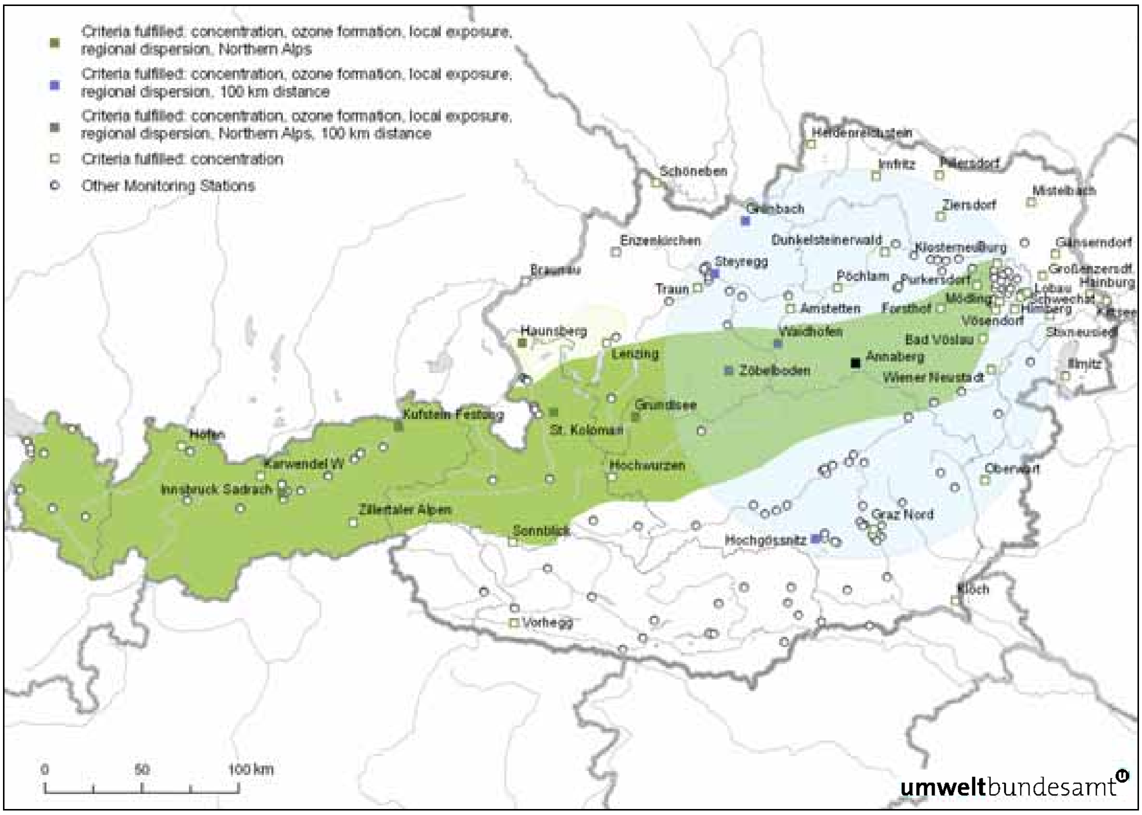

Figure 62: Monitoring stations within the area of representativeness of Annaberg for ozone, different approaches. The green area covers the large-scale topographic region „Alps north of the main Alpine chain", green hatched is the area where the integration either to the northern Alps or to the pre-alpine lowlandsis not unequivocal; the blue circle covers a radius of 100 km around Annaberg.

The concentration criterion applied to the ozone monitoring site **Wien Stephansplatz** in the city centre of Wien, covers only two low-polluted sites in Kärnten (Carinthia) (Spittal and Wolfsberg). The ozone pollution level in Wien Stephansplatz is at the low end of the concentration range observed in Austria, and this monitoring site can be assumed to be representative only of the central parts of Wien.

7.2.6 Assessment of representativeness based on surrogate data

This chapter presents spatial maps of the area of representativeness based on surrogate data (see chapter 5.6).

7.2.6.1 Nitrogen Dioxide

The area of representativeness for the rural background site of **Illmitz** (alt. 117 m) for NO_2 is estimated on the basis of compliance with the various criteria presented in chapter 7.2.2.1.

The input data for the delimitation of the representativeness area are:

- geographic/topographic information
- CORINE Landcover (CLC) data
- TeleAtlas data.

Monitoring data at the near-city rural location Großenzersdorf-Glinzendorf – which has been in operation since the summer 2004 – suggest that a certain area around the agglomeration Wien (estimated to be 25 km around the centre of Wien) could be excluded from the area of representativeness of Illmitz.

The criteria for the delimitation of the representative area are given in Table 62.

Table 62: Criteria for the delimitation of the representativeness area for Illmitz, NO_2.

Large-scale delimitation	Northern Burgenland province, „Wiener Becken” basin and Marchfeld plain as part of the Pannonian Plain (chapter 5.3.3) or, alternatively, a circle with a radius of 100 km.
Regional dispersion situation	absolute altitude below 300 m
Local dispersion situation	CLC classes 1. (urban, industrial and traffic-related areas) and 5.1.1[26] excluded.
Emissions from domestic heating and industry	Area up to 25 km from the centre of Wien excluded.
Emissions from road traffic	TeleAtlas: Vicinity of Functional Road Classes 0 to 3 excluded.

The representative area of Illmitz within the Pannonian Plain (within Austria) is shown in dark green in Figure 63 (*this area includes no other NO_2 monitoring station*). The (larger) representativeness area within the 100 km circle is shown in light green (*this area includes the monitoring sites Streithofen and Trasdorf*).

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[26] Rivers – might be exposed to significant emissions from ships.

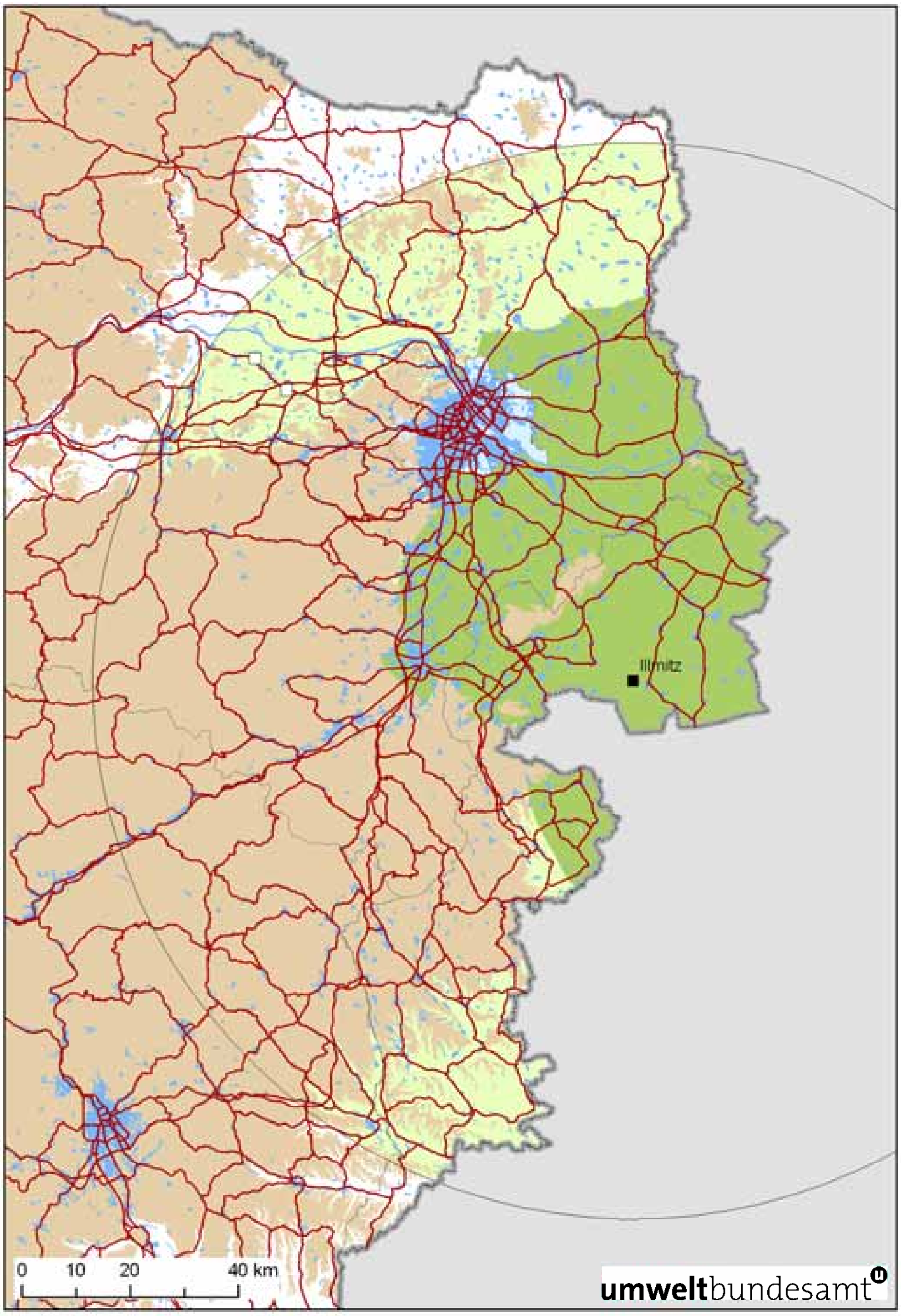

Figure 63: Area of representativeness for Illmitz, NO_2. Areas to be excluded from the area of representativeness: Red: TeleAtlas roads FRC 0 to 3. Dark blue: CLC areas 1.1.1 to 1.4.2 and 5.1.1, light blue: municipality Wien. Brown: Area above 300 m amsl. White squares: Monitoring sites Streithofen and Trasdorf which fulfil the criteria for concentration, emissions, and local and regional dispersion situation. The remaining „area of representativeness" is dark green within the large-scale topographic region „Pannonian Plain", which covers the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain within Austria, and light green within a circle with a radius of 100 km around Illmitz.

The area of representativeness for NO_x for Illmitz is assumed to correspond to that for NO_2 shown in Figure 63.

The area of representativeness for the small town background site Eisenstadt (alt. 182 m), NO_2, is estimated on the basis of the compliance with the various criteria presented in chapter 7.2.2.1.

The input data for delimitation of the representativeness area are:

- geographic/topographic information
- CORINE Landcover (CLC) data
- Population of municipalities
- TeleAtlas data.

The criteria for delimitation of the representative area are given in Table 63.

Table 63: Criteria for the delimitation of the representativeness area for Eisenstadt, NO_2.

Large-scale delimitation	Northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain as part of the Pannonian Plain (chapter 5.3.3) or, alternatively, a circle with a radius of 100 km
Regional dispersion situation	absolute altitude below 350 m
Local dispersion situation Emissions from domestic heating and industry	CLC class 1.1.2 outside Wien
Emissions from domestic heating	Municipalities with 10,000 to 25,000 inhabitants
Emissions from road traffic	TeleAtlas: Vicinity of Functional Road Classes 0 to 3 excluded

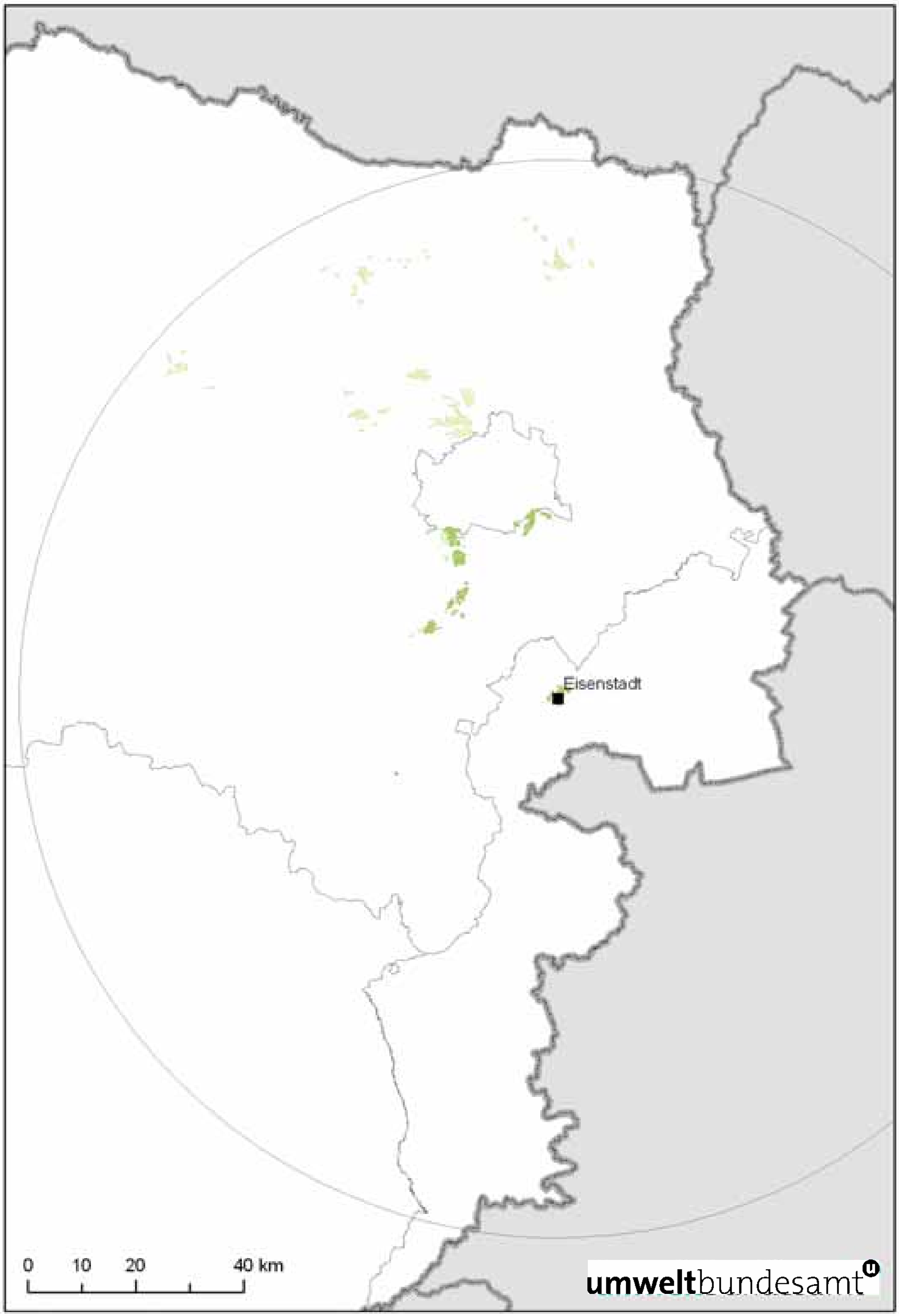

Figure 64: Area of representativeness for Eisenstadt, NO_2. Dark green within the large-scale region „Pannonian Plain", light green within a 100 km circle around Eisenstadt.

The assessment of the area of representativeness of **Wien Belgradplatz** is based upon the compliance with the various criteria presented in 7.2.6.1. Two monitoring sites in Wien, Floridsdorf and Währinger Gürtel, fit all criteria related to Wien Belgradplatz.

The station Belgradplatz is classified as „low” for NO_x traffic emissions and „high” for NO_x domestic heating emissions.

The station is located in a park surrounded by compact buildings; the local dispersion situation is decribed as „one-sided compact or detached buildings”. The regional dispersion situation is described as „plain terrain”, the large-scale region is the Pannonian Plain.

Table 64: Criteria for the delimitation of the representativeness area for Wien Belgradplatz, NO_2.

Large-scale delimitation	Northern Burgenland province, the „Wiener Becken” basin and the Marchfeld plain as part of the Pannonian Plain
Regional dispersion situation	plain (below 350 m)
Local dispersion situation	CLC class 1.1.2 corresponding to one-sided compact or detached buildings
Emissions from domestic heating	above 6.4 t/km²
Emissions from road traffic	TeleAtlas: Vicinity of Functional Road Classes 0 to 3 excluded

The GIS results of these criteria are shown in Figure 65 in dark green. However, Belgradplatz is located in an area within the CLC class 1.1.1 „continuous urban fabric”, which is shown in Figure 65 in light green. The total green area covers the territory with domestic heating NO_x emissions higher than 6.4 t/km² according to the emission inventory.

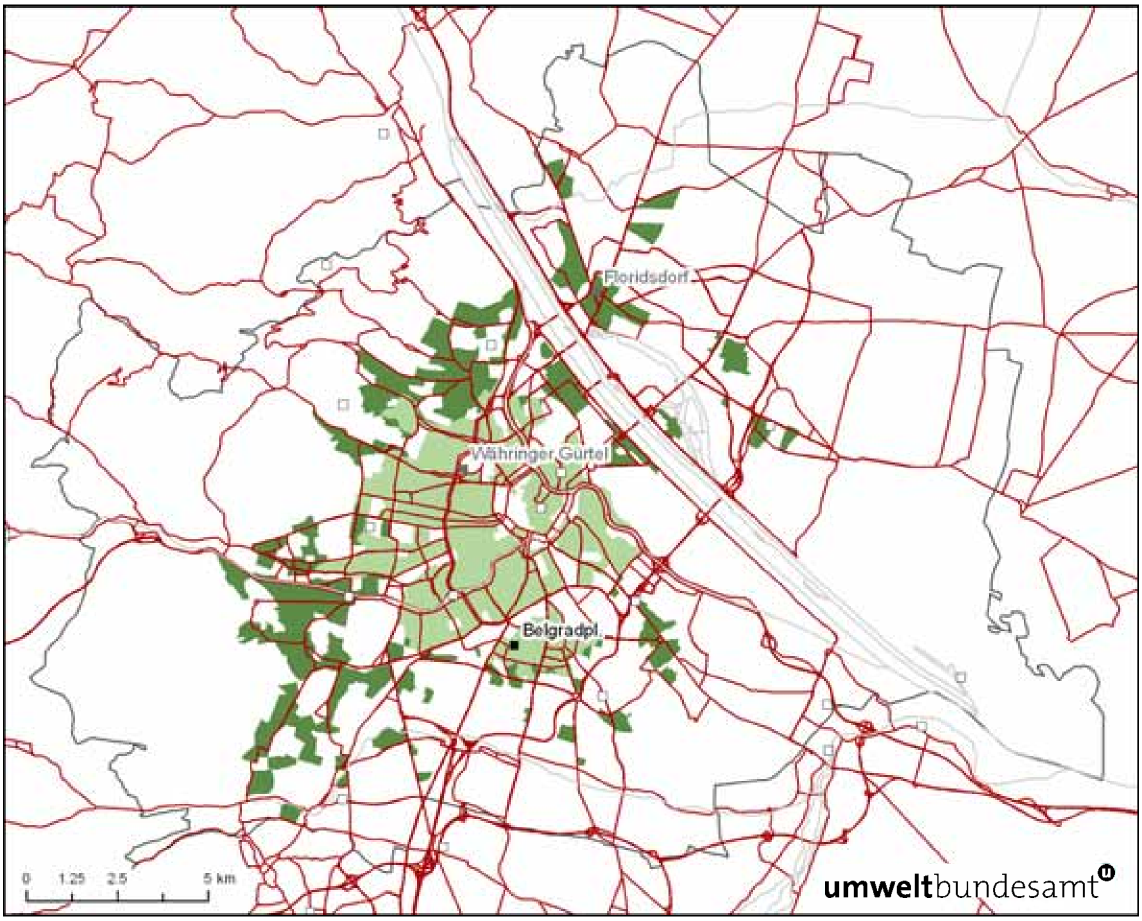

Figure 65: Estimated area of representativeness for Wien Belgradplatz, NO_2. Dark green: CLC class 1.1.2, light green: CLC class 1.1.1, red: TeleAtlas FRC roads 0 to 3.

7.2.6.2 PM10

The assessment of the area of representativeness in the specific case of **Illmitz** is hampered by a possible underestimation of the PM10 correction factors in Niederösterreich (UMWELTBUNDESAMT 2006c), which induce lower PM10 levels in most towns of Niederösterreich than at the rural background site Illmitz.

Based on the findings in chapter 7.2.6.1, the area of representativeness for Illmitz, PM10, is therefore assumed to be the same as for NO_2 (Figure 63).

The assessment of the area of representativeness for **Eisenstadt** is hampered by a possible underestimation of the PM10 correction factors in Niederösterreich, which induce lower PM10 levels in most towns of Niederösterreich compared to Eisenstadt.

The assessment is further complicated by the classification as „medium" of the local road traffic emissions (compared to „low" for NO_x emissions), due to a higher PM10 emission factor in urban traffic.

Table 65 proposes criteria for the delimitation of the representative area for Eisenstadt for PM10, which should, however, be verified using emission inventory data (as soon as these are available).

Table 65: Criteria for the delimitation of the representativeness area for Eisenstadt, PM10.

Large-scale delimitation	Northern Burgenland province, „Wiener Becken" basin and Marchfeld plain as part of the Pannonian Plain (chapter 5.3.3) or, alternatively, a circle with a radius of 100 km
Regional dispersion situation	absolute altitude below 350 m
Local dispersion situation Emissions from domestic heating and industry	CLC class 1.1.2 outside Wien
Emissions from domestic heating	Municipalities with 10,000 to 25,000 inhabitants
Emissions from road traffic	TeleAtlas: Vicinity of 200 along Functional Road Classes 2 to 4

7.2.6.3 Ozone

The spatial assessment of the area of representativeness for **Illmitz** for Ozone is based upon Table 66.

Table 66 suggests the criteria for the delimitation of the representative area. The whole area according to the large-scale delimitation is affected by the increased regional ozone formation in the plume of Wien. The estimated area of representativeness is shown in Figure 66.

Table 66: Criteria for the delimitation of the representative area for Illmitz, ozone.

Large-scale delimitation	Northern Burgenland province, „Wiener Becken" basin and Marchfeld plain as part of the Pannonian Plain (chapter 5.3.3) or, alternatively, a circle with a radius of 100 km
Regional dispersion situation	absolute altitude below 300 m
Local exposure situation	CLC classes 1. excluded in Wien CLC class 1.1.1 excluded outside Wien
Emissions from road traffic	TeleAtlas: Vicinity of Functional Road Classes 0 to 3 excluded

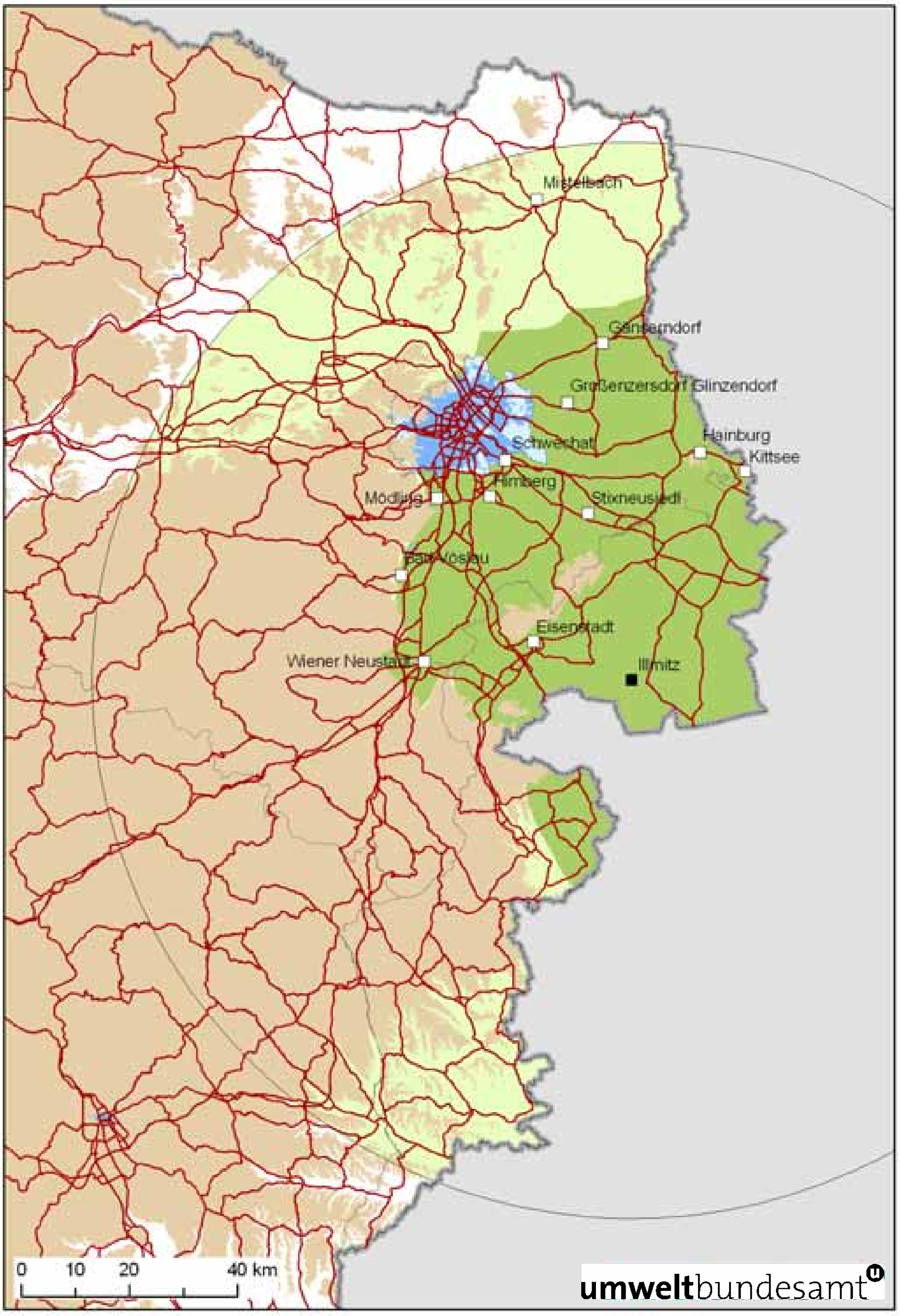

Figure 66: Area of representativeness for Illmitz, ozone. Areas to be excluded from the area of representativeness: Red: TeleAtlas roads FRC 0 to 3. Dark blue: CLC areas 1.1.1 to 1.4.2 and 5.1.1 in Wien (Vienna) and 1.1.1 outside Wien; light blue: municipality Wien. Brown: Area above 300 m amsl. White squares: Monitoring sites which fulfil the criteria for concentration, emissions, and local and regional dispersion situation. The remaining „area of representativeness" is dark green within the large-scale topographic region „Pannonian Plain", which covers the northern Burgenland, Wiener Becken and Marchfeld within Austria, and light green within a circle with a radius of 100 km around Illmitz.

The area of representativeness for ozone for **Annaberg** (see Table 67) may, on the one hand, be delimited according to the large-scale topographic region „Northern Alps" (chapter 5.3.3), or by a circle of 100 km around the monitoring site (5.4). The area of representativeness covers, in any case, rural areas in elevated – but not high – alpine terrain.

Table 67: Criteria for the delimitation of the representativeness area for Annaberg, ozone.

Large-scale delimitation	Northern Alps (chapter 5.3.3) or, alternatively, a circle with a radius of 100 km
Regional dispersion situation	absolute altitude between 500 m and 1500 m
Local exposure situation	CLC classes 1. excluded
Emissions from road traffic	TeleAtlas: Vicinity of Functional Road Classes 0 to 4 excluded

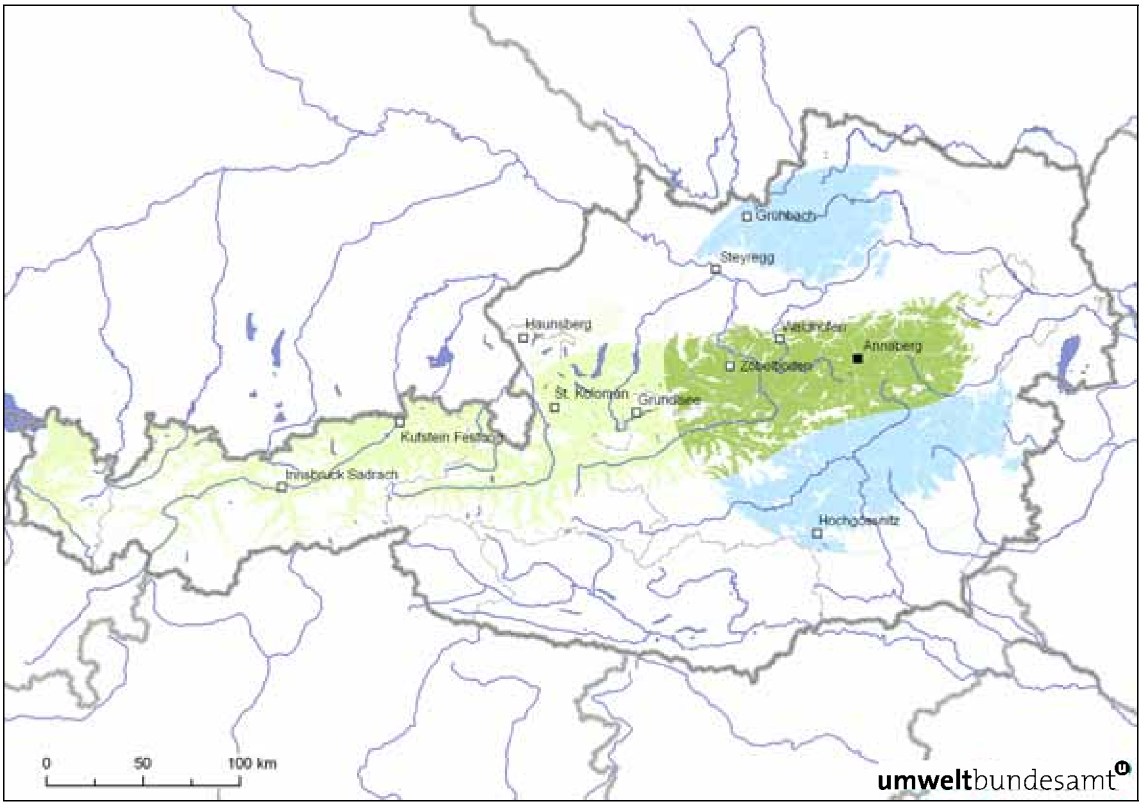

Figure 67: Area of representativeness for Annaberg, Ozone. The green area covers the large-scale topographic region „Alps north of the main Alpine chain", green hatched is the area where integration into either the northern Alps or to the pre-alpine lowlandsis not unequivocal; the blue circle covers a radius of 100 km around Annaberg.

7.2.7 NO_2 passive sampling, Tirol

At several locations in Tirol, the average NO_2 concentration was observed by passive samplers from January 2004 to January 2005 (UMWELTBUNDESAMT 2006a) (Figure 68). These monitoring sites covered locations with annual mean NO_2 concentrations from 3 µg/m³ (background site St. Sigmund, 1666 m altitude, remote alpine valley) to 66 µg/m³ (Vomp A12 Inntal motorway). The monitoring sites in Tirol – both passive sampling sites and continuous (regular) AQ monitoring sites – are listed in Table 68, including the annual mean values for NO_2, the classification according to local road traffic and domestic heating and the classification of the local and regional dispersion situation (industrial influence is low at all monitoring sites).

By way of example, the following tables show the representativeness of the least-polluted site St. Sigmund (Table 69), together with a medium polluted site, Fritzens Bahndamm (annual mean 21 µg/m³, Table 70) and the site with the highest pollution levels (Vomp A12) (Table 71).

Table 68: NO_2 monitoring sites in Tirol; annual mean NO_2 concentration 2004 (µg/m³), classification according to local road traffic and domestic heating emissions, local and regional dispersion situation.

Monitoring site	NO_2	Traffic	Domestic	Local	Regional
St. Sigmund	3	0	0	free	valley
St. Quirin	4	0	0	free	valley
Nordkette	4	0	0	free	mountain
Gries im Sellrain	5	0	0	free	valley
Grinzens	10	0	1	detached	valley
Fritzens, Thierburgweg	12	0	0	free	slope
Fritzens, Eggen	13	0	0	free	slope
Wattens, Kolsassweg 3	16	0	0	free	slope
Wattens, Salzburgerstraße 34	17	0	0	free	valley
Oberperfuss	17	0	0	free	slope
Fritzens, Eichenweg	19	0	0	free	valley
Fritzens, Bahndamm	21	0	0	free	valley
Kematen Ortszentrum	24	0	1	detached	valley
Kramsach	25	0	0	free	slope
Wattens, Kristallwelten	28	1	1	free	valley
Innsbruck Tiergartenstraße	31	0	1	detached	valley
Innsbruck Reichenau	41	1	2	detached	valley
Hall	44	1	1	detached	valley
Innsbruck Zentrum	47	1	1	street canyon	valley
Vomp a.d.L.	49	2	1	free	valley
Völs Einkaufszentrum	50	1	0	free	valley
Wattens, Autobahn	63	2	0	free	valley
Kematen Autobahn	65	2	0	free	valley
Vomp A12	66	2	1	free	valley

Three other sites fulfil the concentration criterion related to St. Sigmund (annual mean 3 µg/m³), which means a maximum NO_2 concentration of 8 µg/m³. The site is classified as „traffic low” and „domestic heating low”, local dispersion is characterised as free air flow and the site is located in a valley. All fall into the lowest emission class both for traffic and domestic heating. Two of them are located in a sparsely populated valley, one on a mountain above Innsbruck.

Table 69: Representativeness criteria fulfilled for St. Sigmund.

Concentration within range	Emissions		Dispersion	
	Traffic	Domestic	local	Regional
St. Quirin	ok	ok	ok	valley
Nordkette	ok	ok	ok	mountain
Gries	ok	ok	ok	valley

The concentration criterion for Fritzens Bahndamm (annual mean 21 µg/m³) covers sites in a concentration range from 16 to 26 µg/m³. All of these are characterised by low traffic emissions, and one of them (Kematen Ortszentrum (town centre), the only site in a built-up area) by medium domestic heating emissions. Three of the sites listed in Table 70 are located in the Inn valley, three at its slopes.

Table 70: Representativeness criteria fulfilled for Fritzens Bahndamm.

Concentration within range	Emissions		Dispersion	
	Traffic	Domestic	local	Regional
Wattens Kolsassweg	ok	ok	free	slope
Wattens Salzburgerstraße	ok	ok	free	valley
Oberperfuß	ok	ok	free	slope
Fritzens Eichenweg	ok	ok	free	valley
Kematen Ortszentrum	ok	medium	built-up	valley
Kramsach	ok	ok	free	slope

The concentration criterion for Vomp A12 is fulfilled by the two other sites in the vicinity of the A12 Inntal motorway. All three sites are classified as „high traffic", but Vomp A12 is classified as „medium" for domestic heating emissions, and the other sites as „low". All sites are located in flat terrain in the Inn valley.

Table 71: Representativeness criteria fulfilled for Vomp A12.

Concentration within range	Emissions		Dispersion	
	Traffic	Domestic	local	Regional
Wattens A12	ok	low	ok	ok
Kematen A12	ok	low	ok	ok

Figure 68: NO_2 passive sampling monitoring sites in Tirol.

7.2.8 Klagenfurt

7.2.8.1 Representativeness on a regional scale

Routine measurement data: **Example: Klagenfurt Koschatstraße, urban background**

The NO_2 annual mean in Klagenfurt Koschatstraße was 32 µg/m³ in 2002, 38 µg/m³ in 2003 and 32 µg/m³ in 2004. The NO_2 monitoring stations which fulfil the concentration criterion (±5 µg/m³ in relation to Klagenfurt Koschatstraße in all years) are listed in Table 72. Klagenfurt Koschatstraße is affected by low traffic and industrial emissions and medium emissions from domestic heating.

Table 72 lists many stations with similar NO_2 levels, but contributions from emissions other than at Klagenfurt Koschatstraße. None of these monitoring sites is in the same class for the regional dispersion situation (basin).

It can be seen that the concentration criterion for NO_2 covers a multitude of monitoring sites in different locations:

- several sites in small towns in alpine valleys;
- several background sites in the agglomeration Wien;
- some sites near rural motorways (Vösendorf, Zederhaus, Wald).

Table 72: Representativeness criteria fulfilled for Klagenfurt Koschatstraße for NO_2.

	Emission			
Concentration within range in all years	**Traffic**	**Domestic H**	**Industrial**	**Dispersion Local**
Vösendorf			ok	
Zederhaus			ok	
Graz Süd	ok	ok		ok
Graz West	ok	ok	ok	ok
Leoben Göss	ok	ok	ok	ok
Kufstein	ok	ok	ok	ok
Wörgl		ok	ok	ok
Dornbirn		ok	ok	ok
Wald a.A.	ok		ok	
Wien Floridsdorf	ok	ok	ok	ok
Wien Gaudenzdorf			ok	ok
Wien Kaiserebersdorf	ok		ok	ok
Wien Laaerberg			ok	ok
Wien Stephansplatz	ok			ok
Wien Währinger Gürtel	ok		ok	ok

7.2.8.2 Modelled NO_2 concentrations in Klagenfurt

Exceedances of the PM10 limit value in Klagenfurt prompted studies investigating the sources and the spatial distribution of air pollution by PM10 and NO_2 in Klagenfurt (TU Graz 2006, 2007). Klagenfurt is a medium-sized town (90,000 inhabitants, some 100,000 including adjacent smaller municipalities) in the „Klagenfurter Becken” basin in Kärnten (Carinthia) in southern Austria.

Figure 69 presents the CORINE Landcover map and the major roads (TeleAtlas FRC 0 to 3) in Klagenfurt.

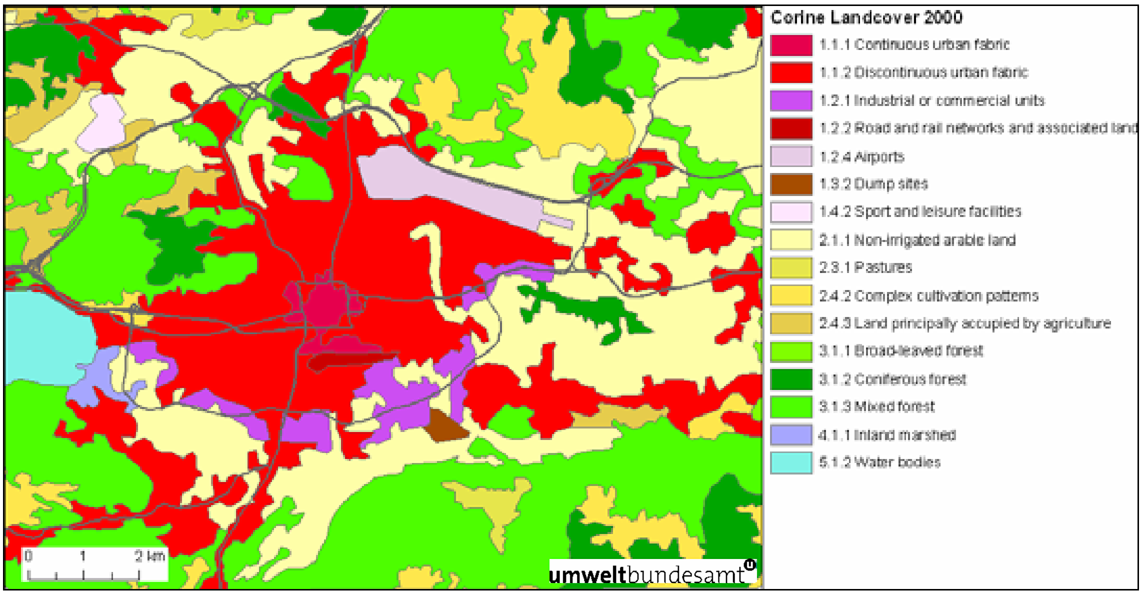

Figure 69: CORINE Landcover map of Klagenfurt.

The modelled annual mean NO_2 concentration is shown in Figure 75.

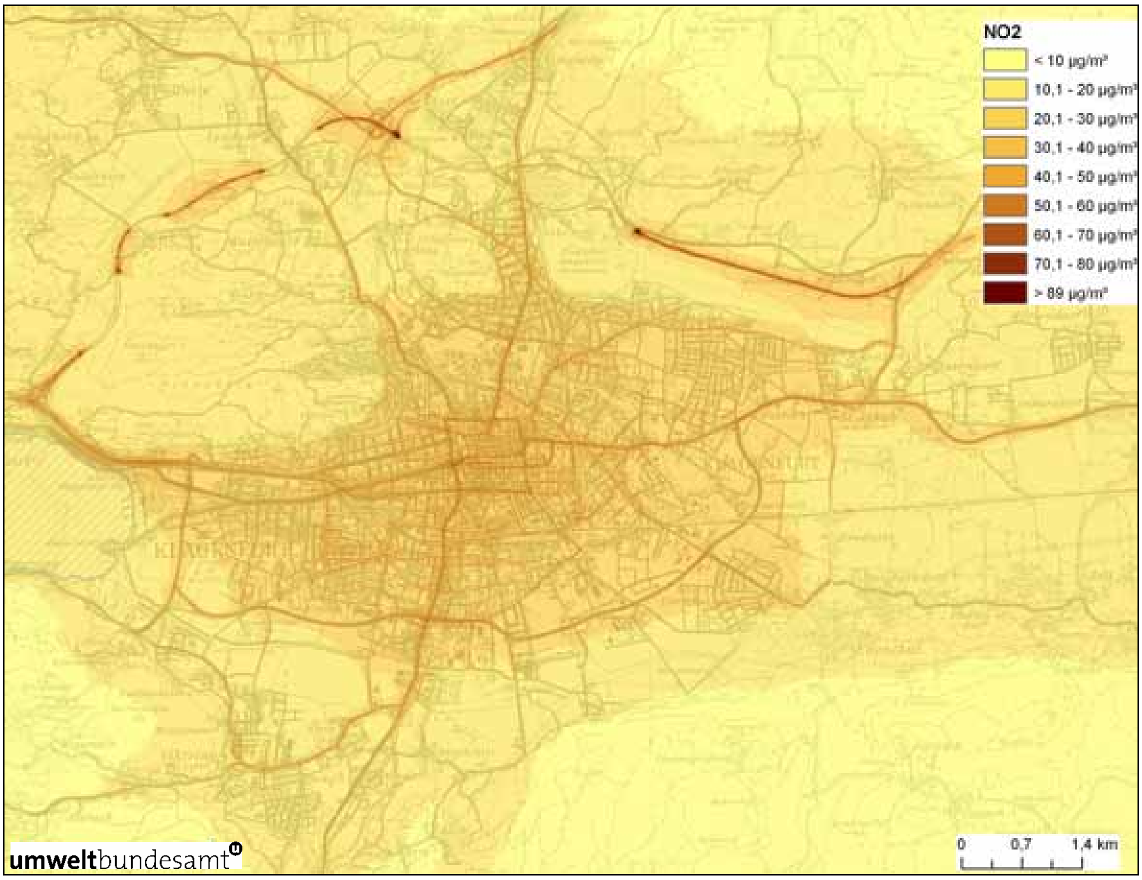

Figure 70: Spatial distribution of the NO_2 annual mean value 2005.

The NO_2 annual mean concentration at the monitoring site Klagenfurt Koschatstraße was 27 µg/m³ in 2005, at Klagenfurt Völkermarkterstraße 43 µg/m³.

According to the concentration criteria proposed in chapter 4.3.3, the area of representativeness for NO_2 covers the concentration range from 22 to 32 µg/m³ for Klagenfurt Koschatstraße and from 38 to 48 µg/m³ for Klagenfurt Völkermarkterstraße. The respective areas are shown according to the modelled concentrations in Figure 75 in yellow for Koschatstraße and in red for Völkermarkterstraße.

According to the criteria proposed in chapter 3.2, the „level 2 classification" of these stations on account of prevailing emissions (chapter 6.5.4) puts Koschatstraße – for NO_x emissions – in „low traffic" and „medium domestic heating" and Völkermarkterstraße in „medium" both for road traffic and domestic heating emissions.

Nevertheless, the modelling shows that at both monitoring sites emissions from road traffic are by far the predominant source of NO_x, accounting for 48% at Koschatstraße and 70% at Völkermarkterstraße. This large contribution is not only to be attributed to local road traffic emissions, but to the emissions in the whole city area. The absolute difference in NO_x (and NO_2) levels between the two sites is, anyhow, caused by local road traffic. Local traffic emissions amount to 0.22 kg/km.h on Koschatstraße and to 0.50 kg/km.h on Völkermarkterstraße, i.e. more than twice the amount of Koschatstraße.

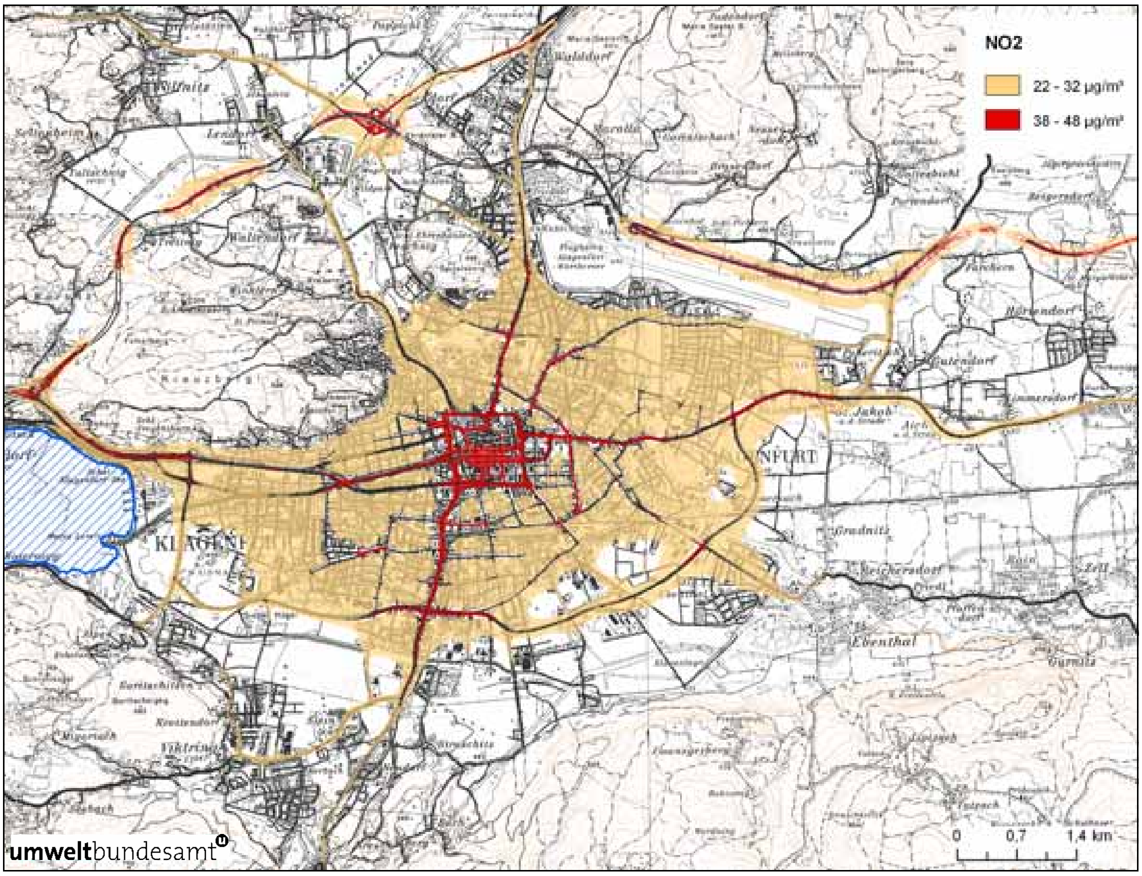

Figure 71: Areas with modelled annual average NO_2 concentrations 2005 within a concentration range ±5 µg/m³ around the annual mean values measured at the monitoring stations Klagenfurt Koschatstraße (yellow) and Klagenfurt Völkermarkterstraße (red).

Figure 71 clearly shows that the area of representativeness of the monitoring station Koschatstraße more or less covers urban background areas, whereas the area of representativeness for Völkermarkterstraße covers the major road network of the city, but also includes the motorway A2 which passes the town in the north and some smaller roads in the city centre, where – besides quite heavy traffic – adverse local dispersion situation in street canyons contribute to elevated NO_2 levels.

The area of representativeness for both stations has to be further limited by criteria regarding emissions and dispersion situation.

The emission criterion for local road traffic will exclude the vicinity of major roads in peripheral areas of the town from the area of representativeness of Koschatstraße („low traffic"), especially the vicinity of the motorway A2 in the north. Also for Völkermarkterstraße („medium traffic") the motorway A2 has to be excluded from the area of representativeness.

Both stations are classified as „medium" with regard to contributions from domestic heating emissions and „low" with regard to the impact from industrial emissions. Corresponding to the above mentioned restrictions regarding road traffic emissions, peripheral areas of the town with low emissions from domestic heating – where high concentrations are dominated by local road traffic, especially in the wider vicinity of the motorway A2 – have to be excluded from the area of representativeness, especially for Koschatstraße.

There are no quantitative data available on the building structure, which would enable identification of the local dispersion situation according to chapter 5.3.1; but street canyon situations are more or less restricted to the city centre (within the square of major roads clearly visible by elevated concentrations), whereas outside the centre detached building structure prevails; these are the surroundings of both sites Koschatstraße and Völkermarkterstraße. No roads classified as „one-sided street canyon" can be found in Klagenfurt.

Since the local dispersion situation is only of relevance for traffic influenced sites, these criteria only apply to Völkermarkterstraße. Street canyons in the very city centre should therefore be excluded from the area of representativeness of this site, as well as non-built-up areas at the periphery of the town alongside major roads, especially the motorway A2.

As surrogate information on both domestic heating emissions and the building structure around the stations Koschatstraße and Völkermarkterstraße, the CORINE Landcover class 1.1.1 Discontinuous urban fabric can be used. The area of representativeness shown in Figure 72 is based upon a combination of the areas fulfilling the concentration criterion (Figure 71) and the CLC class 1.1.2. Some areas along major roads outside the city, which fulfil the concentration criterion for Koschatstraße, should be excluded from the representative area of this station, because local emissions are dominated by road traffic in these areas.

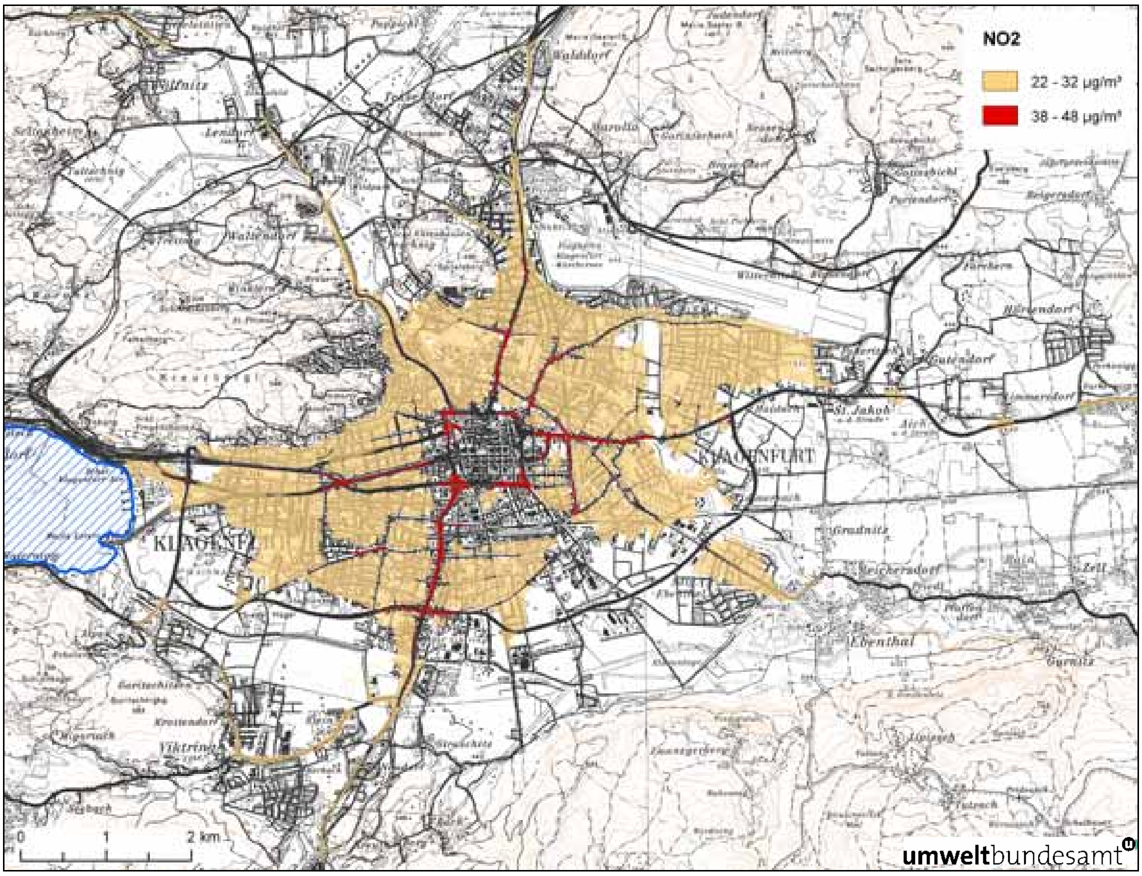

Figure 72: Approximate areas of representativeness of the monitoring sites Klagenfurt Koschatstraße and Völkermarkterstraße for NO_2.

It can be seen clearly that there are large areas – especially in the city centre – outside the area of representativeness for the two monitoring stations in Klagenfurt. The „white" area is characterised by NO_2 annual mean concentrations between 32 and 38 µg/m³ and is therefore not covered by the concentration criterion for Koschatstraße or Völkermarkterstraße.

The regional dispersion situation poses no major restrictions to the area of representativeness, since there is a distinct vertical gradient in the concentrations at the border between the flat terrain where the town is located and the adjacent hills.

Klagenfurt is located in the Klagenfurter Becken, a large basin in the Alps south of the main Alpine chain. Due to the topographic and climatic conditions, the area of representativeness of the monitoring sites in Klagenfurt is confined to this basin. Within this basin, locations with similar concentrations, emissions and local dispersion situation could be included in the area of representativeness of the two monitoring sites in Klagenfurt. This area could especially include similar locations in the second largest town in the Klagenfurter Becken, Villach (55,000 inhabitants).

The approximate delimitation of the area of representativeness for the two monitoring stations in Klagenfurt also gives some information about the area of which these sites are not representative. Areas with distinctly different emission patterns cover especially the motorway A2 outside the city, other major roads outside the city and in its periphery, and rural areas outside the city. Areas with other local dispersion situations cover on the one hand street canyons in the very city centre, on the other hand non built-up areas outside the city.

7.2.8.3 Modelled PM10 concentrations in Klagenfurt

Modelled annual mean PM10 concentration are shown in Figure 78 for the year 2005.

The annual mean PM10 concentrations were 26 µg/m³ at Koschatstraße and 38 µg/m³ at Völkermarkterstraße in 2005.

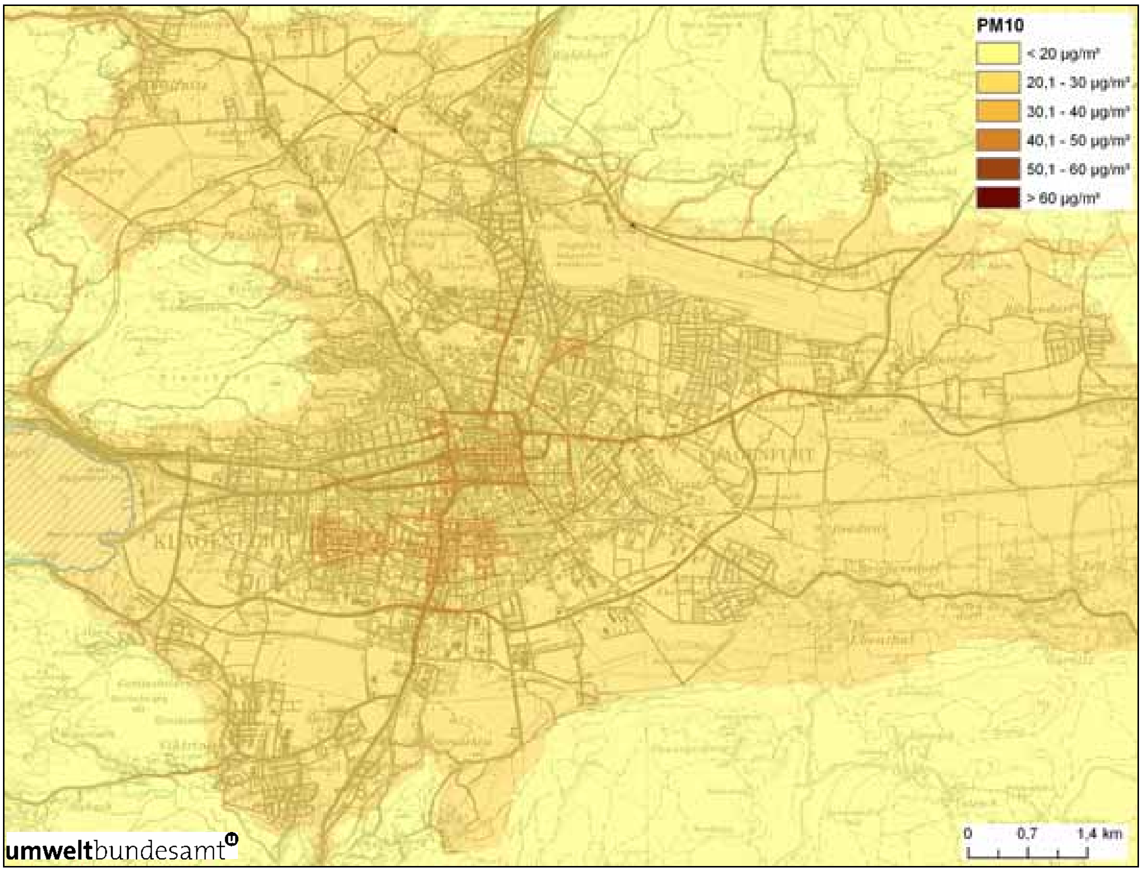

Figure 73: Spatial distribution of the PM10 annual mean value 2005.

According to the concentration criteria proposed in chapter 4.3.3, the area of representativeness for PM10 covers the concentration range from 21 to 31 µg/m³ for Koschatstraße and from 33 to 43 µg/m³ for Völkermarkterstraße. The respective areas are shown – according to the modelled concentrations in Figure 74 – in yellow for Koschatstraße and in red for Völkermarkterstraße.

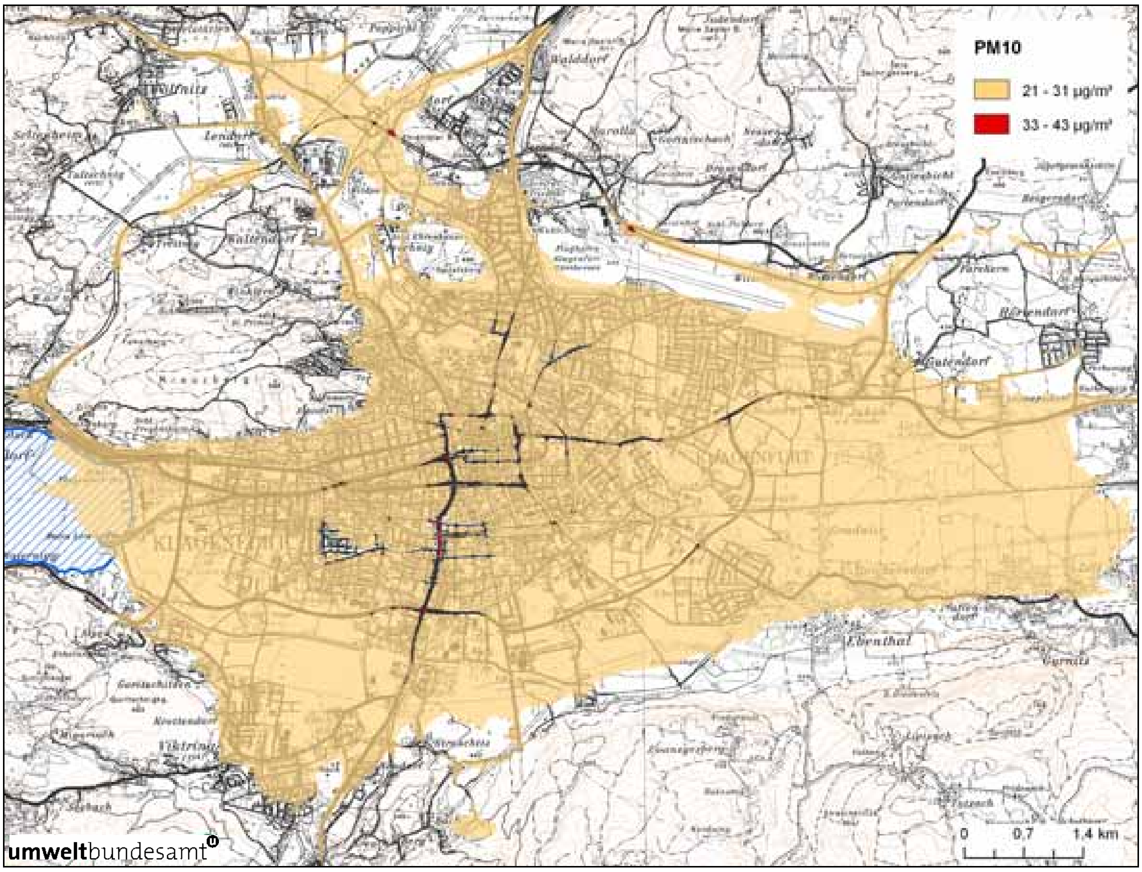

Figure 74: Areas with modelled annual average PM10 concentrations 2005 within a concentration range ±5 µg/m³ around the annual mean values measured at the monitoring stations Klagenfurt Koschatstraße (yellow) and Klagenfurt Völkermarkterstraße (red).

The spatial distribution of the PM10 concentration is smoother than that of NO_2, due to the higher contribution of the regional background (up to 15 µg/m³) and from domestic heating emissions, which are distributed more uniformly than the road traffic emissions dominating the NO_2 concentration pattern.

According to the criteria proposed in chapter 3.2, the „level 2 classification" of these stations on account of prevailing emissions (chapter 6.5.5) puts Koschatstraße – for PM10 emissions – in „medium" both for road traffic and domestic heating emissions, Völkermarkterstraße in „high" for road traffic and in „medium" for heating emissions. Anyhow, the level 3 approach using emission data from the urban emission inventory would result in the classification as „high" with regard to domestic heating for both sites.

The area of representativeness for Koschatstraße delimited by the concentration criterion would cover most of the area of the town, including rural areas in its near vicinity. The application of the emission criterion would restrict the area of representativeness to the central and southern urban regions, and would as well exclude areas in the vicinity of major roads in the periphery of the town, especially near the motorway A2 in the north.

The area which fulfils the concentration criterion for Völkermarkterstraße is quite small and covers only some detached areas alongside major roads. The tunnel entrances of the motorway A2 have to be excluded anyhow.

Regarding the local as well as regional dispersion situation, the same restrictions to the area of representativeness apply as for NO_2.

7.2.9 EMEP sites

This chapter gives a short presentation of the representativeness assessment of Austrian EMEP sites, taking also into account EMEP sites in neighbouring countries.

EMEP sites should, per definition, be representative of very large areas. Related to the EMEP model with a spatial resolution of 50 km, the area of representativeness of EMEP sites should roughly cover a model grid cell. Criteria regarding the representativeness of EMEI sites are given in chapter 2 "Siting criteria" of the EMEP Manual for Sampling and Chemical Analysis[27] (NILU, 2001).

Representativeness is assessed for ozone (low spatial variability) and NO_2 (high spatial variability). Table 73 lists the annual 93.2 percentiles of daily maximum 8-hour ozone mean values and NO_2 annual mean values at EMEP sites in Austria, Slovenia, Hungary, Slovakia, Czech Republic, Germany and Switzerland.

Table 73: Ozone: Annual 93.2 percentiles of daily maximum 8-hour mean values and NO_2 annual mean values at EMEP sites in Austria, Slovenia, Hungary, Slovakia, Czech Republic, Germany and Switzerland, µg/m³.

		Ozone			**NO_2**		
		2002	**2003**	**2004**	**2002**	**2003**	**2004**
AT	Illmitz	129	148	127	9	9	9
AT	Zöbelboden	123	149	127	4	5	5
AT	Vorhegg	125	148	125	3	4	4
SLO	Iskrba	120	141	127			
HU	K-Puszta	146	145	105	5	3	5
SK	Topolniky	121	146				
SK	Stara Lesna	114	127	113			
SK	Starina	116	136	116			
SK	Chopok	127	146	128			
CZ	Svratouch	126	134	115	10	12	9
CZ	Kosetice	124	140	117	5	11	8
DE	Brotjacklriegel	131	147	126	9	7	9
DE	Schmücke	131	162	129	10	10	8
DE	Schauinsland	131	155	145	5	6	5
DE	Deuselbach	120	146	111	11	12	10
CH	Tänikon	129	148	128	14	16	15
CH	Rigi	139	160	135	9	8	7
CH	Payerne	130	151	123	15	17	14
CH	Chaumont	138	160	137	8	9	6

7.2.9.1 Ozone

The concentration criterion (chapter 4.3.3) requires a concentration range of ± 9 µg/m³. It can easily be seen that all three Austrian EMEP sites would be in one representative area if only the concentration criterion is applied.

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[27] http://www.nilu.no/projects/CCC/manual/

In the neighbouring countries, Iskrba, Topolniky (only two of three years' data), Chopok, Brotjacklriegel and Tänikon fulfil the concentration criterion in relation to all three Austrian EMEP sites, Payerne in relation to Illmitz and Vorhegg, Kosetice in relation to Vorhegg.

The Austrian EMEP sites are, however, located in totally different geographical regions: Illmitz (117 m) in the Pannonian Plain, Zöbelboden (900 m) in the Northern Alps, Vorhegg (1020 m) in the Southern Alps.

In the Pannonian Plain (see Figure 25), there are two other EMEP sites besides Illmitz, K-Puszta and Topolniky. K-Puszta clearly does not fulfil the concentration criterion in relation to Illmitz, due to very high ozone levels 2002 and very low levels 2004. Topolniky fulfilled the concentration criterion in 2002 and 2003 (no data from 2004). With respect to the somehow doubtful data from K-Puszta, a delimitation of the area of representativeness in the Pannonian Plain is not really possible.

The concentration criterion is also fulfilled in relation to Illmitz by several sites at higher altitude, Chopok (2008 m), Brotjacklriegel (1016) and Tänikon (540 m), but at no other EMEP site in a vicinity of 500 km.

In the Northern Alps, the EMEP sites Zöbelboden and Rigi (1030 m) are situated at medium altitude, with much higher concentrations at Rigi (not fulfilling the concentration criterion), which might be due to the exposed situation on a summit, compared to the complex terrain around Zöbelboden. Among the EMEP sites at closer distance, only Brotjacklriegel fulfils the concentration criterion. At lower altitudes, Tänikon fulfils the concentration criterion; it might be discussed whether Tanikon should be located in the Alps instead of the Northern alpine foothills.

The area of representativenss of Zöbelboden resembles that of Annaberg (Figure 67), covering medium altitudes in the Northern Alps, and, as it may be discussed, in the southern Bohemian Massif. Whether exposed summits – like Rigi – at altitudes about 1000 m in the Austrian Northern Alps should be excluded due to significantly higher Ozone levels cannot be decided.

Vorhegg in the Southern Alps fulfils the concentration criterion in relation to several sites north and north-east of the Alps in completely different geographical locations. The concentration criterion is also fulfilled with somehow nearby Iskrba (540 m), and it may be discussed that Iskrba should be located in the Southern Alps, in the South-eastern Pre-Alpine Lowlands or in the Dinaric Mountains. However, the difference in altitude makes is questionable whether Vorhegg and Iskrba should be put into the same representative area.

7.2.9.2 NO_2

Most of the EMEP sites listed in Table 73 have higher NO_2 annueal mean values than the Austrian sites. The concentration criterion (± 5 µg/m³) in relation to Illmitz is fulfilled by Svratouch, Kosetice, Brotjacklriegel, Schmücke, Schaunsland, Deutselbach, Rigi and Chaumont, i.e. by elevated sites. K-Puszta in the Pannonian Plain does not fulfil the concentration criterion due to lower NO_2 levels in 2003; there are no data from the Slovakian and Slovenian sites.

The concentration criterion in relation to Zöbelboden is fulfilled at several elevated sites – Brotjacklriegel, Schauinsland, Rigi and Chaumont – but also K-Puszta. Nevertheless, the annual average NO_2 concentrations at Zöbelboden (900 m) are clearly lower than at Brotjacklriegel, Rigi and Chaumont and comparable to Schauinsland (1205 m), thus reflecting the very remote location of Zöbelboden.

Similar to Ozone, the area of representativenss of Zöbelboden covers medium altitudes in the Northern Alps, and, as it may be discussed, in the southern Bohemian Massif, but in addition also all higher altitudes, since the concentration criterion covers a range from 0 to 10 µg/m³.

The concentration criterion in relation to Vorhegg (with average NO_2 concentration around 4 µg/m³ the lowest polluted site in central Europe) is fulfilled by Schauinsland, Chaumont and also K-Puszta.

The comparison with other Austrian monitoring stations shows that the representative area of Vorhegg covers all medium and high mountains in Southern Austria.

7.2.9.3 Spatial coverage

The EMEP monitoring network shows quite different spatial distributions in each country (see Figure 25). The three Austrian EMEP sites are distributed across different large-scale geographical units, the Pannonian Plain, the Northern and the Southern Alps.

In the Czech Republic, both EMEP sites are located in a quite a central position, Svratouch (737 m) in the Bohemian Massif, and the allocation of Kosetice to either the Bohemian Massif or the central Bohemian Basin is open to discussion. In Slovakia, four sites are crowded together in the mountainous north-eastern part at quite different altitudes and location types. Switzerland operates 5 EMEP sites at different locations.

There seems to be a general tendency to locate EMEP sites at higher altitudes, which corresponds to the requirement of low emission densities in the vicinity of EMEP sites, a criterion which is more easily to be met in mountainous areas.

Considering the large-scale geographical units with different topographic and climatic conditions delimited in Figure 25, the EMEP sites are not at all equally distributed to these regions. The Alps – north and south – are covered by EMEP sites in Austria and Switzerland, but not at all in France and Italy. The Bohemian Massif is covered by EMEP stations in the Czech Republic, in Germany and in Poland. Strikingly, the region „Jura, Vosges, Schwarzwald, Alb” hosts four EMEP sites (Montandon, Donon, Chaumont, Schauinsland).

On the contrary, there are no EMEP sites e.g. in the region „Weinviertel and Moravia” and the Upper Rhine Valley, and the Northern pre-alpine lowlandslack EMEP sites in Austria and Germany, but there are two stations in Switzerland. EMEP monitoring sites within the German Mountains are „crowded” together in the western part of this region (Deuselbach, Eupen, Offagne, Revin).

The EMEP site Ispra is seen as representative of hilly terrain in the transition area between the Po Valley and the Southern Alps. But it should be kept in mind that the station is operated in Ispra not because of the representativeness (or remoteness) of this location, but because of the JRC which is based there.

More information on the spatial distribution on the EMEP monitoring sites and its implications can be found in the EMEP PM Status Report (YTTRI ET AL. 2007).

7.3 Netherlands, Rijnmond area

7.3.1 Nitrogen dioxide

In the Netherlands the Rijnmond area was used for validation of the method for the assessment of representativeness.

For the Rijnmond area – i.e. the agglomeration of Rotterdam and the adjacent industrial and harbour regions – emission data and modelling results of annual NO_2 and PM10 concentrations were provided (Figure 75 and Figure 78) by TNO.

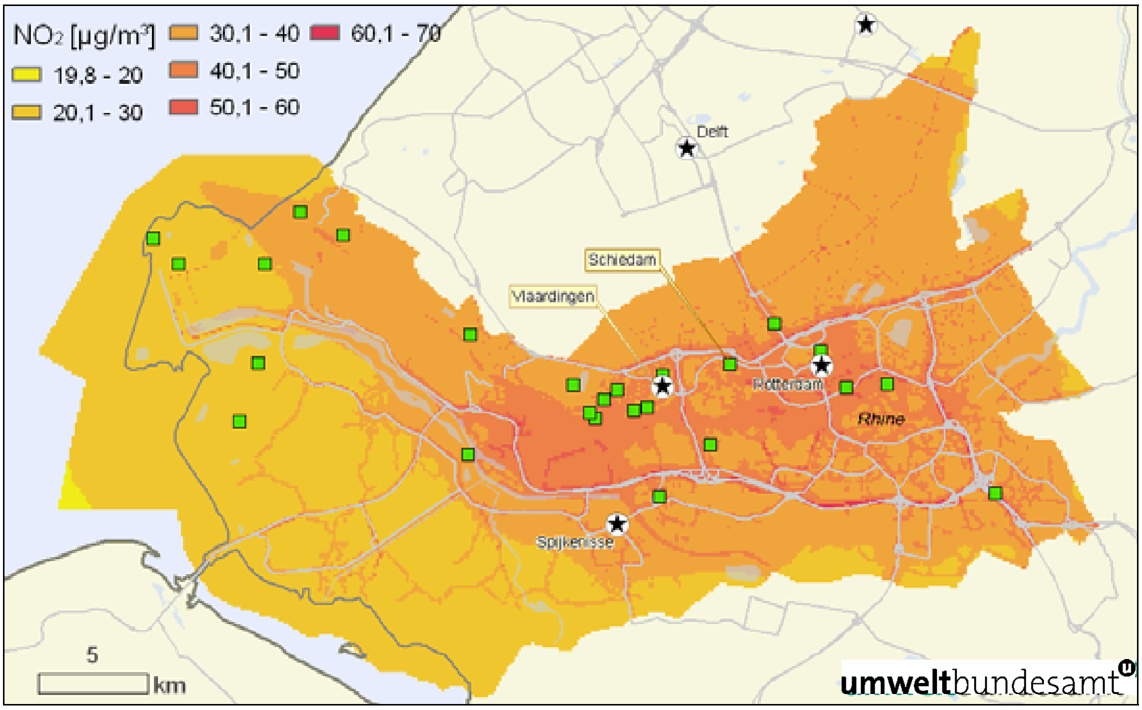

Figure 75: Modelled NO_2 annual mean concentration 2004, µg/m³.

The annual mean NO_2 concentrations measured in 2004 cover a range from 34 µg/m³ at Maassluis Kwartallaan and 54 µg/m³ at Overschie A13. The spatial pattern of modelled NO_2 concentrations is dominated by the major road network. Elevated NO_2 concentrations between 40 and 50 µg/m³ on a scale of several kilometres cover the urbanised areas of Rotterdam and Vlaardingen, whereas the industrialised western area of Europoort has lower concentrations around 30 µg/m³.

The area of representativeness is assessed for the monitoring stations Schiedam Alphons Arienstraat (annual NO_2 mean value 2004 40 µg/m³) and Ridderkerk (53 µg/m³). The concentration criterion according to Table 20 giving a concentration range ±5 µg/m³ both for the annual mean of NO_2 and PM10 yields in a concentration range from 35 to 45 µg/m³ for Schiedam Alphons Arienstraat and from 48 to 58 µg/m³ for Ridderkerk. The respective areas are shown in Figure 76.

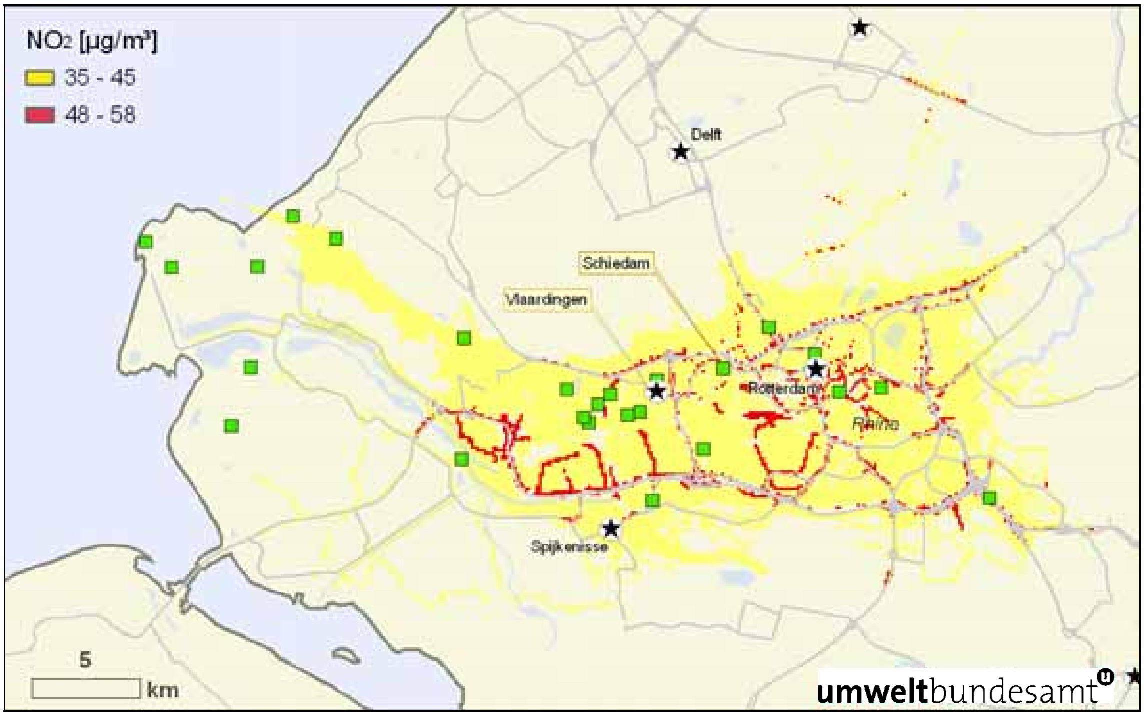

Figure 76: Area fulfilling the concentration criterion for representativeness of the monitoring stations Schiedam Alphons Arienstraat (yellow) and Ridderkerk (red).

It can be seen that the area within the concentration range representative of Schiedam Alphons Ariestraat obviously covers parts of the road network with medium emissions.

Gridded emissions from domestic heating are available for the Rijnmond area and allow applicaion of the criterion for NO_x emission densities from domestic heating (the class boundary of 20 t per year within a radius of 1 km roughly corresponds to an emission density of 6 t per km²). The area in Rotterdam fulfilling both the concentration criterion and the emission classification for Schiedam Alphons Ariestrat is orange coloured in Figure 77. Still this „area of representativeness" covers traffic influenced suburban locations which should be excluded. No emission data from road traffic are available in an appropriate GIS format, nor is there information about the building structure, and therefore these criteria can not be applied to further delimitate the area of representativeness.

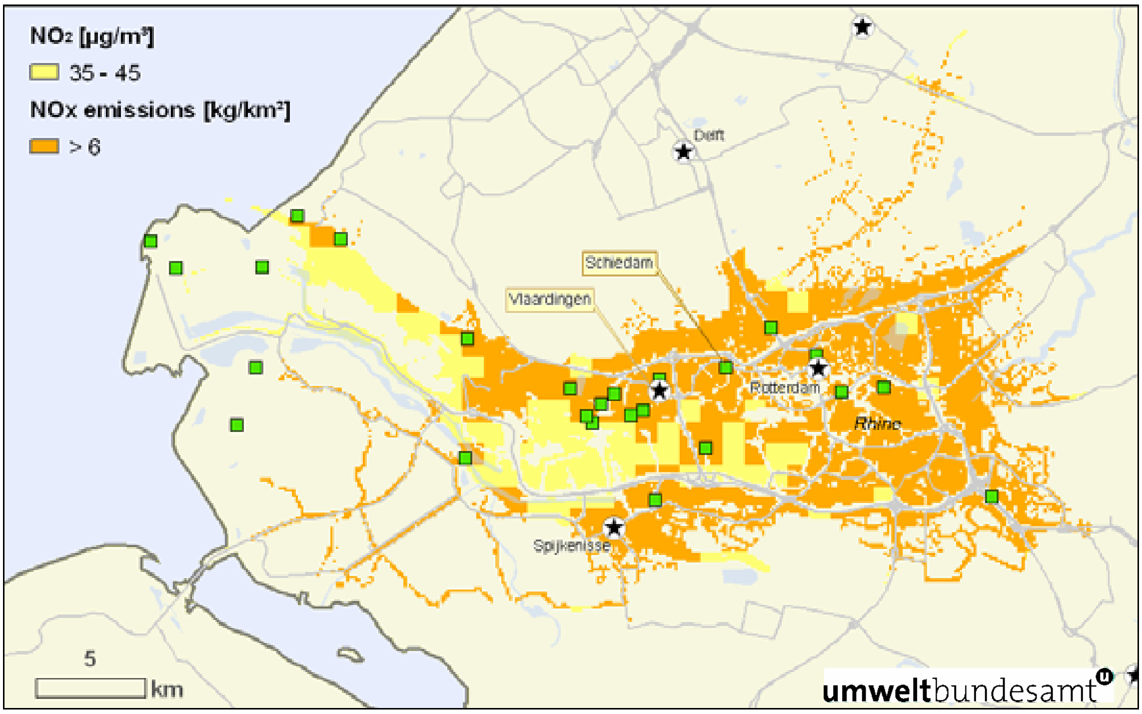

Figure 77: Area fulfilling the concentration criterion for representativeness of the monitoring stations Schiedam Alphons Arienstraat (yellow) and in addition the cirtieria for NO_x emission densities from domestic heating (orange).

7.3.2 PM10

The spatial concentration pattern of PM10 is quite smooth over most parts of the Rijnmond area. The urbanised regions in Rotterdam and Vlaardingen are affected by concentrations between 30 and 40 µg/m³; the major road network has only a minor influence on the PM10 concentrations.

The measured annual mean values vary in a small range between 28 and 36 µg/m³, the highest concentration observed at Rotterdam Schiedamsevest.

The model, however, shows that much higher concentrations occur in some parts of the Rijnmond area due to point sources. In the western Europoort area, PM10 levels above 120 µg/m³ are calculated. As Figure 78 shows, the areas of elevated PM10 concentrations above 40 µg/m³ are not covered by the monitoring network.

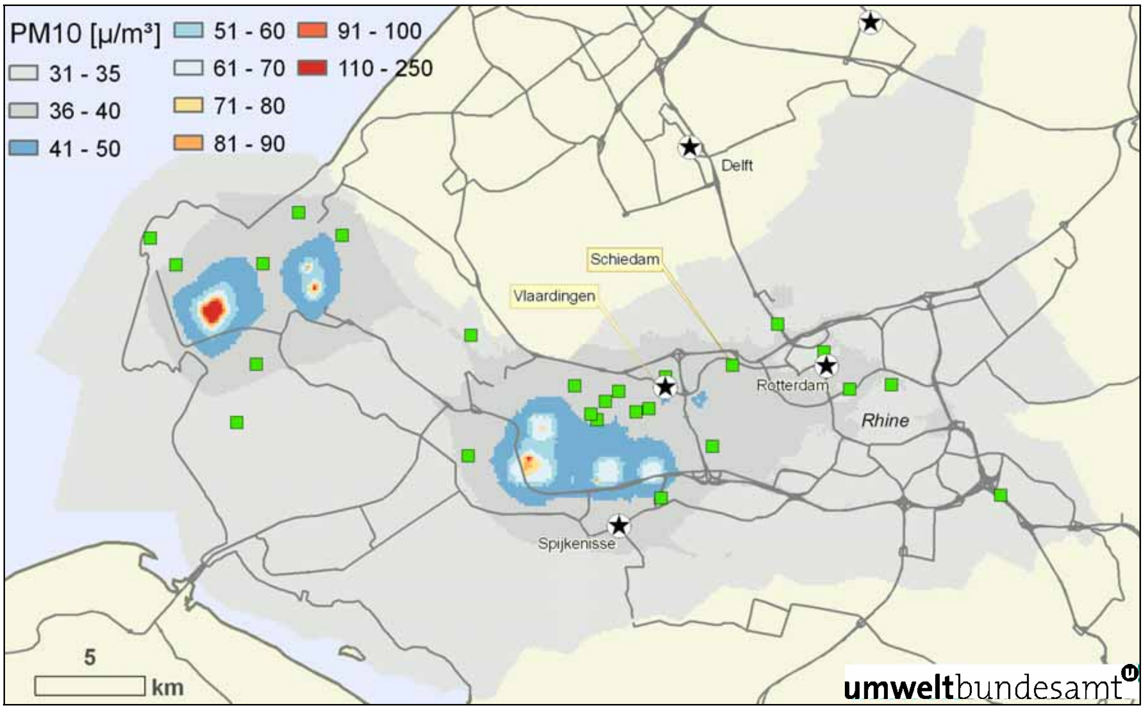

Figure 78: Modelled PM10 annual mean concentration 2004, µg/m³.

With respect to the smooth pattern of PM10 concentrations in most parts of the Rijnmond area and the fact that no monitoring station is affected by the high concentration plumes, the concentration criterion for the PM10 annual mean does not really delimit the areas of representativeness of most of the existing monitoring stations.

7.3.3 Ozone

The Dutch ozone monitoring stations were checked according to the concentration criterion. The topographic situation is equal for all Durch sites (flat), the ozone formation potential is assessed as high for the whole territory. The local exposure situation is assumed as open terrain for all sites.

No accurate information is available for the local NO_x emissions, and therefore this criterion can not be checked.

The monitoring sites which fulfil the concentration criterion for Amsterdam Florapark, a low polluted background site in an agglomeration, and Dordrecht Firsostraat, a medium polluted site in a smaller town, are listed in Table 74.

Table 74: Monitoring sites in the Netherlands fulfilling the concentration criterion for ozone in relation to Amsterdam Florapark and Dordrecht Firsostraat.

Amsterdam Florapark	Dordrecht Firsostraat
	Biddighuizen Hoekwantweg
	Biest Houtakter Biestestaat
Breukelen Snelweg	
	Cabauw Zijdeweg
Den Haag Rebecquenstraat	Den Haag Rebecquenstraat
	Hujbergen Vannekenstraat
	Philippine Stelleweg
Schipluiden Groenveld	Schipluiden Groenveld
Utrecht de Jongweg	
Utrecht Ezzejstaat	
	Utrecht Univ.bibl.
	Valtermond Norderdijk
Vlaardingen Floreslaan	
	Wekerom Riemterdijk
Westmaas Groenweg	Westmaas Groenweg
Wieringerwerf Medemblikkerweg	Wieringerwerf Medemblikkerweg
	Zegveld Oude Meije
	Zierikzee Lange Silkeweg

Figure 79: Monitoring sites in the Netherlands fulfilling the concentration criterion for ozone in relation to Amsterdam Florapark (red) and Dordrecht Firsostraat (blue).

7.4 English monitoring stations

In Great Britain, two areas were used for the validation of the method for the assessment of representativeness:

- London for the urban scale;
- northern central England for the regional scale.

Modelled concentrations of NO_2 and PM10 on a 1 km grid have been provided by AEAT.

7.4.1 London

The modelled annual mean concentrations for the year 2004 are shown for NO_2 in Figure 80 and for PM10 in Figure 81.

The PM10 model results in most cases overestimate measured urban background concentrations. For example, London Bloomsbury measured an annual mean PM10 concentration of 20 µg/m³, compared to a modelled concentration of about 27 µg/m³.

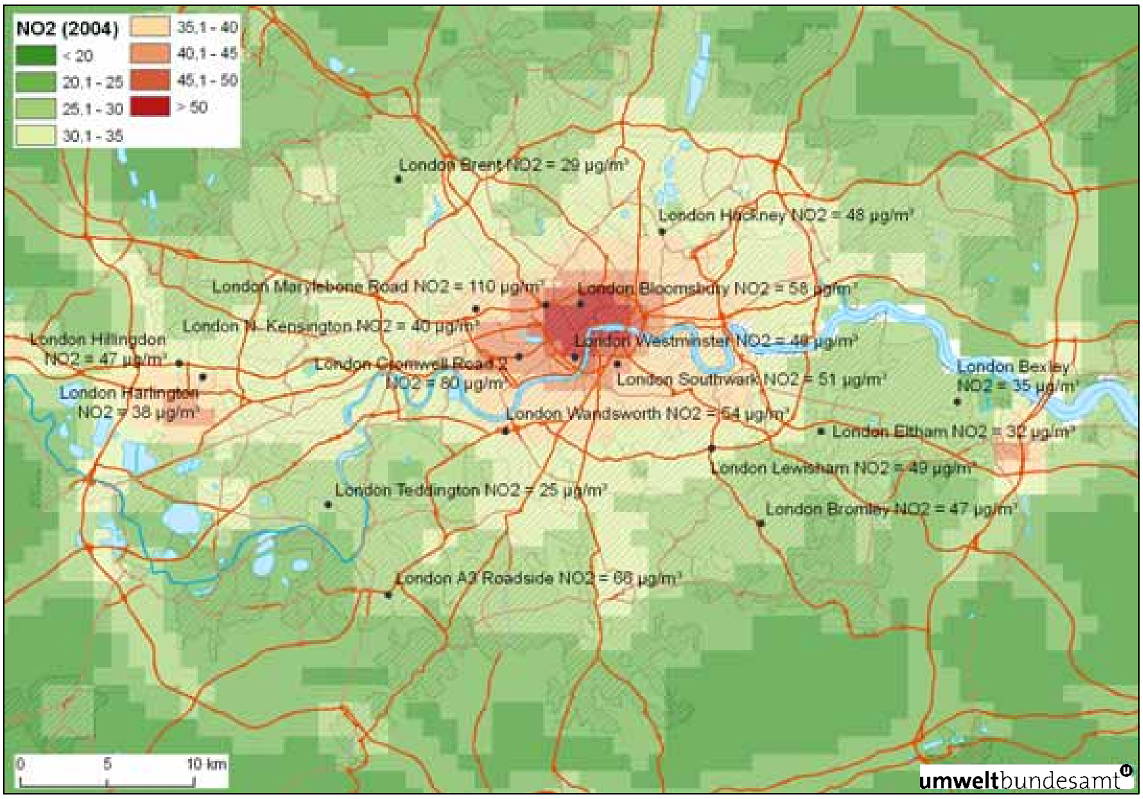

Figure 80: Modelled annual mean NO_2 concentrations 2004, London area.

The assessment of representativeness is limited to the concentration criterion, since no emission data are available at present. It can be assumed that the regional dispersion situation are totally uniform due to the flat terrain.

Related to the spatial resolution of 1 km, the assessment of representativeness is limited to urban or suburban background stations.

Two background sites are selected for the assessment of representativeness: London Westminster measured an annual mean NO_2 concentration of 46 µg/m³ in 2004. The area fulfilling the concentration criterion (NO_2 annual mean 41 to 51 µg/m³) covers most of the central London area between Kensington and the City.

London Teddington as a suburban background site observed an annual mean NO_2 concentration of 25 µg/m³. The concentration criterion (20 to 30 µg/m³) is fulfilled in a large area covering most of the suburban regions within and outside the agglomeration of London.

The PM10 concentration is, even in the urban background, more uniform, covering a concentration range between 22 and 31 µg/m³ for most of the agglomeration.

London Westminster observed an annual mean PM10 concentration of 27 µg/m³, which means that the concentration criterion (±5 µg/m³) is fulfilled in almost the whole area shown in Figure 81.

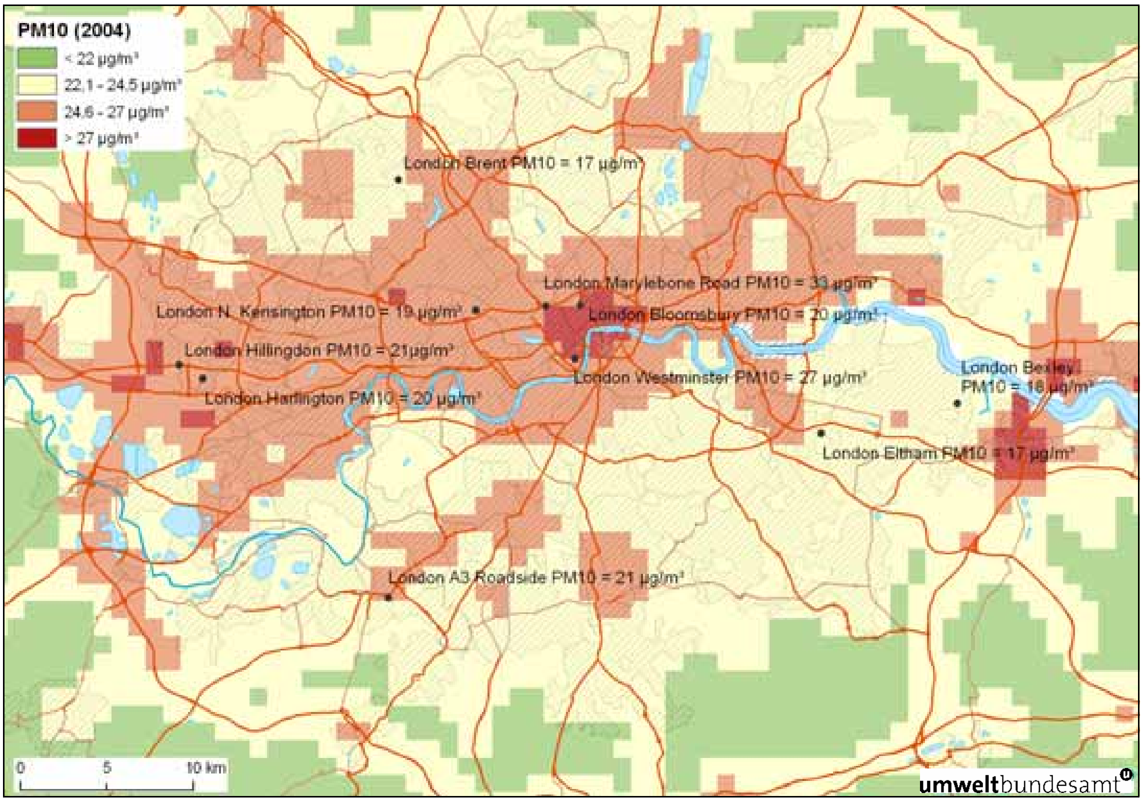

Figure 81: Modelled annual mean PM10 concentrations 2004, London area.

7.4.2 Northern central England

The modelled annual mean NO_2 concentrations in northern England – the area between Merseyside and West Yorkshire – for 2004 is shown in Figure 82, including the NO_2 monitoring stations with measured concentrations for 2004. The model clearly shows the high concentrations on the urban scale in the agglomerations Manchester, Leeds and Sheffield (above 25 µg/m³), and along the major rural highways.

On the other hand, there are large rural areas, especially in the Pennine Range, in Wales, and to the north in Yorkshire and Cumbria, with very low annual mean NO_2 concentrations below 10 µg/m³.

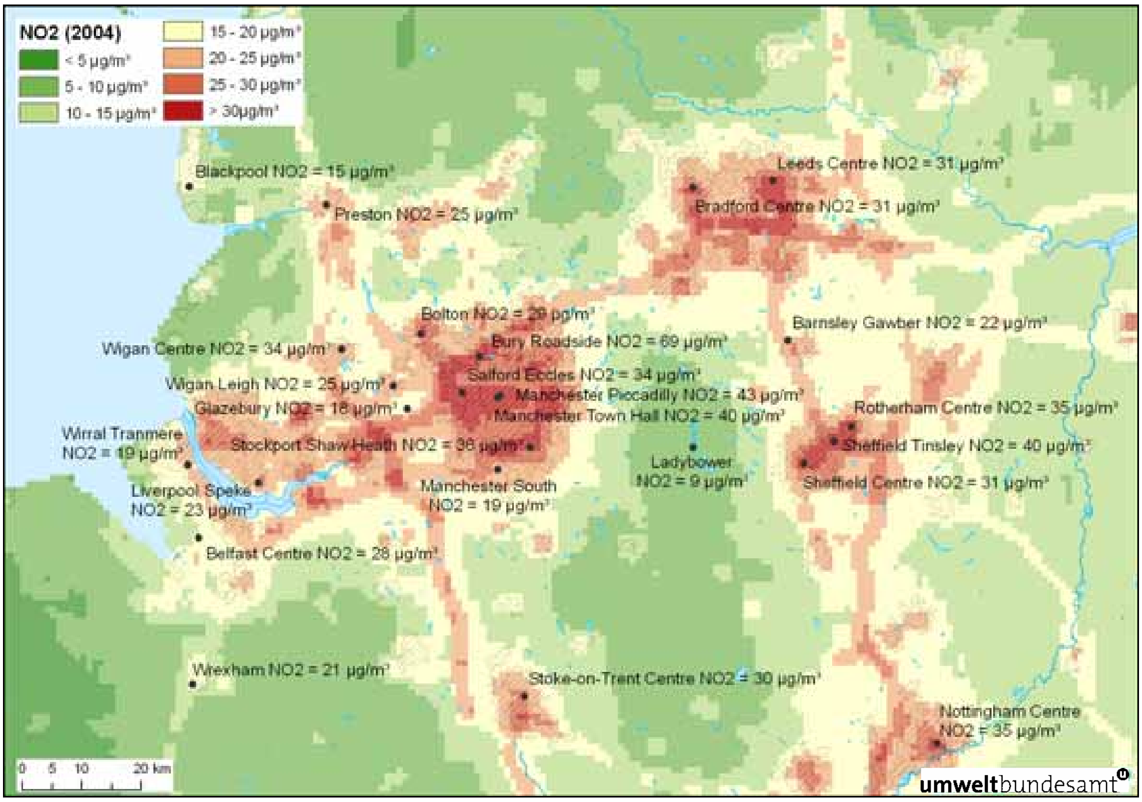

Figure 82: Modelled annual mean NO_2 concentrations for northern central England.

The area of representativeness for certain monitoring stations could be delimited according to the concentration criterion. For example, the area of representativeness for the urban site Bolton (annual mean 29 µg/m³) would cover most of the central urban areas of the larger towns in the region, excluding kerb side locations, where NO_2 annual mean values up to 69 µg/m³ are measured.

There is no information about emissions, building structure and dispersion situation available; therefore a complete assessment of representativeness is not possible. It might be assumed that the comparably low NO_2 concentrations in the agglomeration Liverpool – compared to Manchester – can be attributed to a more favourable dispersion situation at the seashore; also, the area east of the Pennine chain could be affected by a more unfavourable dispersion situation compared to its western side.

7.5 Sensitivity of the concentration criterion

In this chapter, the sensitivity of the extension of the representativeness area related to the concentration criterion given in Table 20 is tested for the Austrian monitoring stations which are analysed in chapter 7.2. Areas of representativeness are not determined specifically for various concentration criteria, but concentrations measured at available monitoring stations are compared to the concentration criteria.

7.5.1 Nitrogen Dioxide

The sensitivity of the area of representativeness is tested for the rural background site Illmitz (see Figure 63) and the urban background site Wien Belgradplatz (see Figure 65).

The following situations are compared:

- extending the concentration range for the annual mean NO_2 concentration by 50% from ±5 µg/m³ to ±7.5 µg/m³
- reducing the concentration range by 50% to ±2.5 µg/m³.

7.5.1.1 Illmitz

The area of representativeness of Illmitz for NO_2 within the large scale topographic region of the northern Burgenland province, the „Wiener Becken" basin and the Marchfeld plain includes, by extending the concentration criterion to ±7.5 µg/m³, the NO_2 monitoring stations *Bad Vöslau and Gänserndorf*, i.e. suburban sites near small towns. Within a maximum distance of 100 km, the area of representativeness would include in addition the rural sites *Neusiedl i.T. and Zwentendorf* in the Tullnerfeld plain.

The area of representativeness for Illmitz, when applying a concentration criterion of ±2.5 µg/m³, covers no other monitoring station within the northern Burgenland, the Wiener Becken and the Marchfeld or within a distance of 100 km. Outside the Pannonian Basin, the monitoring stations Forsthof and Pillersdorf fulfil this concentration criterion.

7.5.1.2 Wien Belgradplatz

By extending the concentration criterion to ±7.5 µg/m³ the area of representativeness for Wien Belgradplatz for NO_2 within within a radius of 100 km would additionally include the monitoring sites *St. Pölten Europaplatz, Vösendorf, in Wien Kaiserebersdorf, Kendlerstraße, Liesing, Stephansplatz and Taborstraße*. These are monitoring sites with medium impact from local road traffic (St. Pölten Europaplatz, Vösendorf, Taborstraße), and the other sites are urban background sites in Wien with regard to NO_2.

By reducing the concentration range to ±2.5 µg/m³, the only other monitoring site in Austria fulfilling the concentration criterion would be Wien Gaudenzdorf.

7.5.2 PM10

For PM10, the following situations are compared:

- extending the concentration range for the annual mean PM10 concentration by 50% from ±5 µg/m³ to ±7.5 µg/m³ and for the 90.4 percentile of the daily mean values from 8 to 12 µg/m³
- reducing the concentration range for the annual mean by 50% to ±2.5 µg/m³ and for the 90.4 percentile of the daily mean values from 8 to 4 µg/m³.

7.5.2.1 Illmitz

For Illmitz, the extension of the concentration criterion would include – within in the northern Burgenland province, the „Wiener Becken" and the Marchfeld plain – the sites *Wien Lobau and Wien Währinger Gürtel*. Within a radius of 100 km, *Oberwart and Mürzzuschlag* would be included. Most sites in the province of Niederösterreich fulfil the criterion for the annual mean, but not for the 90.4 percentile.

The reduced concentration criterion is fulfilled – within a radius of 100 km – by Wien Kaiserebersdorf and Wien Laaerberg, outside this distance also Pillersdorf (for all three sites, only PM10 data from two years are available).

7.5.2.2 Wien Belgradplatz

For Wien Belgradplatz, the extension of the concentration criterion would provide no change compared to the results of chapter 7.2.6.1. Any PM10 monitoring site within a radius of 100 km and fitting into the criteria for emissions and dispersion situation fulfils the concentration criterion of Table 20.

The reduced concentration criterion would restrict the area of representativeness to *Wien Kendlerstraße* and *Wien Währinger Gürtel* (two and 1 years' data, respectively). Within Wien, the annual mean is the more stringent criterion, regarding rural and small town sites the 90.4 percentile.

7.5.3 Ozone

For ozone, the following situations are compared for Illmitz and Annaberg:

- extending the concentration range for the 93.2 percentile for the daily maximum 8-hour mean values by 50 % from 9 to 13.5 µg/m³
- reducing the concentration range for the 93.2 percentile of the daily maximum 8-hour mean values from 9 to 4.5 µg/m³

7.5.3.1 Illmitz

The extension of the concentration criterion by +50 % would include, within the northern Burgenland province, the „Wiener Becken" and the Marchfeld plain – irrespective of the criteria for emissions and local and regional dispersion situation – the ozone monitoring sites *Eisenstadt and Wien Hohe Warte*; and within a radius of 100 km also *Krems, Payerbach, St. Pölten Eybnerstr., Stockerau, Wiesmath, Wolkersdorf and Masenberg*. Except the central urban site Wien Stephansplatz, *all* ozone monitoring stations within this circle would fulfil the concentration criterion.

The reduced concentration range would restrict the area of representativeness to the monitoring sites *Bad Vöslau, Glinzendorf, Himberg, Stixneusiedl and Wiener Neustadt* within the northern Burgenland, the Wiener Becken and the Marchfeld, thus excluding – compared to the concentration range of 9 µg/m³ – Kittsee, Gänserndorf, Mödling, and Schwechat, with lower ozone concentrations in at least one year. On the other hand, several sites in quite different locations – including high mountains – spread all over Austria still fulfil the reduced concentration criterion: Vorhegg, Annaberg, Dunkelsteinerwald, Pillersdorf, Grünbach, Hochwurzen, Klöch and Zillertaler Alpen.

7.5.3.2 Annaberg

The concentration range of 13.5 µg/m³ applied to Annaberg includes – in addition to the monitoring stations listed in Table 90 – the monitoring sites Gerlitzen, Kollmitzberg, Krems, Payerbach, St. Pölten Eybnerstraße, Stockerau, Wiesmath, Wolkersdorf, Hallein Winterstall, Arnfels, Bockberg, Masenberg, Piber, Nordkette, Lustenau, Sulzberg and Wien Hermannskogel.

Within the Northern Alps, the sites Payerbach, Nordkette, Sulzberg and Wien Hermannskogel are located; therefore the concentration criterion of 13.5 µg/m³ covers *all* ozone monitoring sites in the Northern Alps.

A concentration range of 4.5 µg/m³ will cover very few monitoring stations in very different types of locations: Illmitz, Vorhegg Großenzersdorf Glinzendorf, Stixneusiedl, Grünbach, and Zöbelboden. These are a) some highly polluted sites in the Pannonian Plain and b) some sites at very similar altitudes to Annaberg, among which only Zöbelboden is located in the Northern Alps.

In conclusion, the Austrian data show that the area of representativeness is in many cases quite sensitive to the concentration criteria. When using extended concentration ranges, areas of representativeness would mostly be delimitated by other representativeness criteria, rather than by concentrations. When using smaller concentration ranges, areas of representativeness would mostly be delimitated by concentration criteria.

7.6 Statistical parameters – Austrian data

As stated in chapter 5.7, statistical parameters represent a completely different approach to assess the spatial variability of concentrations. As discussed there, the root mean square difference (RMSD) would be considered the most appropriate parameter for a representativeness assessment.

The following chapters discuss the results of the RMSD calculation for the Austrian AQ monitoring network in relation to the representativeness assessed on the basis of the definition provided in chapter 4.

7.6.1 Austria, NO_2 1-hour mean values

The results of the statistical parameters presented in chapter 5.7.1 are discussed in greater detail for those Austrian monitoring sites, for which the delimitation of a representative area is shown in chapter 7.2.

For **Illmitz**_(NO_2), Table 75 compares those monitoring stations which fulfil the concentration criterion of ±5 µg/m³ of the annual mean value (according to chapter 4.3) and those for which the RMSD related to Illmitz is below 10 µg/m³. Monitoring sites fulfilling also the criteria for local and regional dispersion are printed in bold.

The two totally different criteria are fulfilled both for almost the same stations. The concentration criterion for the annual mean is fulfilled also for some monitoring sites in the Niederösterreich province, for which the **RMSD** is higher than 10 µg/m³. Several alpine sites with low pollution level do not fulfil the concentration criterion, but the RMSD related to Illmitz is below 10 µg/m³.

Table 75: Monitoring stations which fulfil the concentration criterion of ±5 µg/m³ of the annual mean value (left) and those for which the RMSD related to Illmitz is below 10 µg/m³ (right); bold: monitoring sites fulfilling also the criteria for dispersion.

Annual mean within ±5 µg/m³ of the NO_2 annual mean value in Illmitz	RMSD with Illmitz below 10 µg/m³
Obervellach	Obervellach
St. Georgen	Soboth
Dunkelsteinerwald	Vorhegg
Forsthof	Dunkelsteinerwald
Heidenreichstein	Forsthof
Kollmitzberg	Gänserndorf
Payerbach	**Neusiedl i.T.**
Pillersdorf	Payerbach
Streithofen	**Pillersdorf**
Trasdorf	**Streithofen**
Tulbinger Kogel	Tulbinger Kogel
Waidhofen a.d.Y.	Waidhofen a.d.Y.
Enzenkirchen	**Wolkersdorf**
Grünbach	Enzenkirchen
Zöbelboden	Grünbach
Haunsberg	Zöbelboden
Hochgössnitz	Haunsberg
Piber	Hochgössnitz
Pöls	Masenberg
Sulzberg	Piber
	Pöls
	Nordkette
	St. Sigmund
	Sulzberg

It should be noted that except Gänserndorf all these monitoring sites show **correlations** with Illmitz below 0.6 (Gänserndorf below 0.7), which means that this statistical measure for similarity gives a completely different picture.

The **coefficient of divergence** (COD) is higher than 0.25 (and therefore not checked in detail) for any pair of monitoring sites related to Illmitz.

The monitoring sites in **Klagenfurt** (Koschatstraße and Völkermarkterstraße) do not show a **RMSD** value below 10 µg/m³ in relation to any other monitoring site.

The two monitoring sites correlate between each other between 0.8 and 0.9 (but with none higher than 0.8). Klagenfurt Koschatstraße shows **correlations** between 0.7 and 0.8 with Spittal, St. Andrä, Villach, Wolfsberg, Deutschlandsberg, Knittelfeld, Voitsberg Krems and Voitsberg Mühlgasse. This covers most of the Kärnten province and the adjacent parts of the Steiermark province (Styria).

Klagenfurt Völkermarkterstraße shows correlations between 0.7 and 0.8 with Spittal, St. Andrä, Wolfsberg and Graz Don Bosco.

CODs between 0.20 and 0.25 connect the two sites in Klagenfurt, and connect Koschatstraße further with Villach and Wolfsberg, Völkermarkterstraße further with Graz Mitte and Innsbruck Zentrum, i.e. highly polluted sites at larger distances.

Wien Belgradplatz is linked only to Wien Gaudenzdorf by a **RSMD** value below 10 µg/m³.

The concentration criterion (±5 µg/m³ of the annual mean) is fulfilled for Gaudenzdorf, Floridsdorf and Währinger Gürtel in Wien, but also for several sites with medium pollution level throughout Austria (St. Pölten Europaplatz, Linz 24er Turm, Linz Neue Welt, Linz Urfahr, Salzburg Lehen, Salzburg Mirabellplatz, Zederhaus, Graz Süd, Kufstein, Lienz, Dornbirn).

High **correlations** above 0.9 connect Belgradplatz to several background sites in Wien (Gaudenzdorf, Kendlerstr., Stephansplatz, Taborstraße, Währinger Gürtel), between 0.8 and 0.9 with Mödling, Wien Floridsdorf, Hohe Warte, Kaiserebersdorf, Laaerberg, Liesing and Rinnböckstraße; the distinctly traffic influenced site Hietzinger Kai shows a correlation below 0.6. It can clearly be seen that high correlations clearly correspond to the short distance between these sites.

Almost the same sites are connected with Belgradplatz by **CODs** below 0.25; CODs below 0.2 occur for Gaudenzdorf, Stephansplatz, Währinger Gürtel and Floridsdorf.

7.6.2 Austria, PM10 daily mean values

The **RMSD** for the daily mean values of PM10 in relation to **Illmitz** is below 10 µg/m³ only for Kittsee, Wien Gaudenzdorf and Wien Stadlau.

Many more sites fulfil the concentration criteria for PM10 (annual mean and 90.4 percentile of the daily mean values), scattered throughout Austria, and covering also Belgradplatz, Gaudenzdorf, Floridsdorf, Kaiserebersdorf, Kendlerstraße, Laaerberg, Schafbergbad and Währinger Gürtel in Wien, but not Stadlau.

The **correlation** coefficient is higher than 0.9 for Eisenstadt, between 0.8 and 0.9 for several sites in north-eastern Austria, covering those with a RMSD below 10 µg/m³.

The only site with a **COD** below 0.15 is Eisenstadt.

The concentration criteria for **Klagenfurt Völkermarkterstraße** (at Klagenfurt Koschatstraße PM10 monitoring started in 2005, it is not included in the statistics) is fulfilled by the monitoring sites Wolfsberg, Linz Römerberg, Hartberg and Weiz, i.e. highly polluted sites at totally different locations.

No site shows a **RMSD** below 10 µg/m³ related to Klagenfurt Völkermarkterstraße.

Villach, Wolfsberg and Graz Don Bosco show correlations between 0.8 and 0.9 related to Völkermarkterstraße.

Villach is the only site with a **COD** below 0.15 related to Völkermarkterstraße.

Wien Belgradplatz shows **RMSD** values below 10 µg/m³ in relation to Eisenstadt and the following stations in Wien: Gaudenzdorf, Liesing and Stadlau.

In comparison, the concentration criteria for the annual mean and the 90.4 percentile of the daily mean values are fulfilled for Eisrnstadt, Illmitz, Linz Neue Welt, Linz ORF-Zentrum, Graz Nord, Hall i.T., Feldkirch, in Wien Gaudenzdorf, Floridsdorf, Kaiserebersdorf, Kendlerstraße, Laaerberg, Stadlau and Währinger Gürtel.

Correlation coefficients above 0.8 connect Wien Belgradplatz to many background sites in Wien, Burgenland and Niederösterreich (i.e. in a vicinity of several 10 km), but also some higher polluted sites in Oberösterreich.

The different statistical parameters cover more or less the same set of monitoring sites, mainly background stations in the wider vicinity of Wien. On the contrary, the concentration criterion for the annual mean and the 90.4 percentile of the daily mean values covers medium polluted sites throughout Austria. To delimit the area of representativeness, additional criteria like emissions and dispersion are necessary.

Table 76: Monitoring sites fulfilling the statistical criteria related to Wien Belgradplatz, PM10.

Annual mean within ±5 µg/m³ of the PM10 annual mean value in Wien Belgradplatz, 90.4 percentile of daily mean values within ±8 µg/m³	RMSD below 10 µg/m³	Correlation coefficient >0.8 (bold: >0.9)	COD< 0.15 (bold <0.10)
Eisenstadt, Illmitz, Linz Neue Welt, Linz ORF-Zentrum, Graz Nord, Hall i.T., Feldkirch, Wien Floridsdorf, Wien Gaudenzdorf, Wien Ksisderebersdorf, Wien Kendlerstraße, Wien Laaerberg, Wien Stadlau, Wien Währinger Gürtel	Eisenstadt, Wien Gaudenzdorf, Wien Liesing, Wien Stadlau	**Eisenstadt**, Illmitz, Kittsee, Brunn a.G., Himberg, Klosterneuburg, Mistelbach, Mödling, Schwechat, Stixneusiedl, Stockerau, Wiener Neustadt, Enns, Linz Neue Welt, **Wien Gaudenzdorf**, **Wien Liesing**, **Wien Rinnböckstraße**, Wien Schafbergbad, Wien Stadlau	Eisenstadt, Schwechat, **Wien Gaudenzdorf**, Wien Liesing, Wien Rinnböckstraße, Wien Stadlau

7.6.3 Ozone

The statistical analysis of the ozone concentration, based on the maximum daily 1-hour mean values, shows that the correlations within Austria are higher compared to NO_2 1-hour mean values and PM10 daily mean values; correlation coefficients higher than 0.9 connect stations over distances of more than 100 km. On the other hand, the RMSD values are higher – thus giving „lower similarity" – compared to NO_2 1-hour mean values and PM10 daily mean values, which can be attributed to the overall higher numerical values of ozone concentrations.

Table 77 lists those monitoring sites which fulfil the concentration criterion for ozone according to chapter 4.3, the monitoring sites linked with **Illmitz** by a RMSD below 0.15 µg/m³, by a correlation coefficient higher than 0.90 and a COD below 0.15.

Table 77: Monitoring sites fulfilling the statistical criteria related to Illmitz, Ozone.

93.2 percentile of daily maximum 8-hour mean values within ±9 µg/m³	**RMSD with Illmitz below 15 µg/m³**	**Correlation coeffictient >0.90 (bold: >0.95)**	**COD< 0.15 (bold <0.10)**
Kittsee, Oberwart, Gerlitzen, Vorhegg, Amstetten, Annaberg, Dunkelsteinerwald, Forsthof, Gänserndorf, Hainburg, Himberg, Irnfritz, Klosterneuburg, Mistelbach, Pillersdorf, Mödling, Pöchlarn, Purkersdorf, Schwechat, Stixneusiedl, Vösendorf, Ziersdorf, Wiener Neustadt, Enzenkirchen, Grünbach, Lenzing, Schöneben, Steyregg, Zöbelboden, Hallein Winterstall, Haunsberg, Sonnblick, St. Koloman, Arnfels, Bockberg, Graz Nord, Grundlsee, Hochgössnitz, Hochwurzen, Klöch, Piber, Innsbruck Sadrach, Karwendel West, Kufstein, Nordkette, Zillertaler Alpen, Wien Hermannskogel, Wien Lobau	Eisenstadt, Kittsee, Oberwart, Bad Vöslau, Forsthof, Gänserndorf, Hainburg, Stixneusiedl, Wien Hermannskogel, Wien Lobau	Eisenstadt, Kittsee, Oberwart, Bad Vöslau, Dunkelsteinerwald, Forsthof, Gänserndorf, Hainburg, Heidenreichstein, Himberg, Irnfritz, Klosrterneuburg, Kollmitzberg, Mistelbach, Mödling, Pillersdorf, Pöchlarn, St. Pölten, Schwechat, Stockerau, Stixneusiedl, Streithofen, Ternitz, Wiener Neustadt, Wiesmath, Wolkersdorf, Graz Platte, Graz Schlossberg, Hartberg, Klöch, Weiz, Wien Hermannskogel, Wien Hohe Warte, Wien Laaerberg, Wien Lobau, Wien Stephansplatz	Eisenstadt, Kittsee, Oberwart, Annaberg, Bad Vöslau, Dunkelsteinerwald, Forsthof, Gänserndorf, Hainburg, Heidenreichstein, Himberg, Irnfritz, Klosterneuburg, Kollmitzberg, Mistelbach, Mödling, Payerbach, Pillersdorf, Schwechat, Streithofen, Ternitz, Waidhofen, Wiener Neustadt, Stixneusiedl, Wiesmath, Wolkersdorf, Enzenkirchen, Grünbach, Schöneben, Zöbelboden, Haunsberg, Arnfels, Bockberg, Graz Platte, Grundlsee, Hochwurzen, Wien Hermannskogel, Wien Laaerberg, Wien Lobau

All parameters cover more ore less similar groups of monitoring stations: most sites in the wider vicinity of Illmitz in north-eastern Austria, as well as highly polluted sites throughout Austria. Especially the concentration criteria defined in this study and the **COD** connect high alpine sites with high average ozone pollution with Illmitz; this points to the fact that the absolute concentration level is assessed by these statistical parameters, which clearly do not account for the surroundings of the monitoring site, the temporal variation of ozone concentrations and its causes.

Table 78 lists those monitoring sites which fulfil the concentration criterion for ozone according to chapter 4.3, the monitoring sites linked with **Annaberg** by a RMSD below 0.15 µg/m³, by a correlation coefficient higher than 0.90 and a COD below 0.15.

Table 78: Monitoring sites fulfilling the statistical criteria related to Annaberg, Ozone.

93.2 percentile of daily maximum 8-hour mean values within ±9 µg/m³	RMSD with Illmitz below 15 µg/m³	Correlation coefficient >0.90 (bold: >0.95)	COD< 0.15 (bold <0.10)
Illmitz, Vorhegg, Amstetten, Bad Vöslau, Dunkelsteinerwald, Forsthof, Gänserndorf, Hainburg, Himberg, Irnfritz, Klosterneuburg, Kollmitzberg, Mistelbach, Mödling, Payerbach, Pillersdorf, Pöchlarn, Purkersdorf, Schwechat, Stixneusiedl, Vösendorf, Wiener Neustadt, Ziersdorf, Enzenkirchen, Grünbach, Lenzing, Steyregg, Zöbelboden, Schöneben, Haunsberg, St. Koloman, Sonnblick, Graz Nord, Grundlsee, Karwendel West, Zillertaler Alpen, Wien Lobau	Wiesmath, Grünbach, Schöneben, Zöbelboden, St. Koloman, Grundlsee, Masenberg	Forsthof, Heidenreichstein, Mistelbach, Payerbach, Waidhofen, Wiesmath, Grünbach, Schöneben, Zöbelboden, Hallein Winterstall, Haunsberg, St. Koloman, Arnfels, Graz Platte, Grundlsee	Gerlitzen, Soboth, Vorhegg, Forsthof, Heidenreichstein, Mistelbach, Payerbach, Wiesmath, Grünbach, Schöneben, Zöbelboden, Hallein Winterstall, Haunsberg, Sonnblick, St. Koloman, Arnfels, Graz Platte, Grundlsee, Höfgen, Karwendel West, Nordkette, Zillertaler Alpen, St. Sigmund, Sulzberg

Like Illmitz, the concentration criteria according to chapter 4.3 and the **COD** cover monitoring stations throughout Austria, including high polluted high alpine sites. The **correlation** and the **RMSD** cover a more compact group of rural background sites distributed over large parts of eastern and northern Austria.

7.7 Further development of the assessment of representativeness

In this study, the approach for determining the representative area was tested using data from Austra, the Netherlands and the United Kingdom. As a next step, it should be applied in test cases in other countries. Based on implementation experience, the method can be further developed. Harmonisation should be a constant emphasis of these efforts.

Different procedures using different input data sets should be pursued and evaluated. The following levels of input data have to be compared:

- model data, emission inventories and information on the local dispersion situation available
- no model data, but emission inventories and information on the local dispersion situation available; the spatial concentration distribution has to be assessed by surrogate information (emissions and dispersion situation)
- no model data and no emission inventories are available; the spatial concentration distribution and the distribution of emissions have to be assessed by surrogate information (land use data, e.g. CorineAir, road information, e.g. TeleAtlas roads, topographic information).

The method should be tested in various parts of Europe with different climatic and topographic conditions, in order to evaluate, refine and revise the classification of the regional and large-scale dispersion situations. Close cooperation between the respective AQ monitoring network operators, the team which has developed this study, EC and EEA seems necessary. Financing of appropriate projects should be discussed. In order to achieve international comparability of datasets and facilitate the development of joint services under GEOSS, comparability with the approaches taken in international networks, in the USA, etc. should be monitored.

8 VALIDATION OF DATA AVAILABILITY

Various types of data have been used both to develop the proposed methods for the classification and assessment of the representativeness of monitoring stations, as well as for the test and validation of the methods. The following chapter gives a summary of the experiences gained in obtaining these data, of the sources and origins of these data and the restrictions of their accessibility.

8.1 Sources of data used for method development and validation

The development of the methods for classification and representativeness assessment were based on very different types of data and more qualitative information:

- air quality monitoring data
- air quality model data
- emission data
- topographic information
- surrogate data for the estimation of emissions, e.g. information on the road network, traffic frequency, population distribution, land use …

Data are available on different levels:

- Europe (EU, EEA)
- National
- Municipal or provincial

Data are compiled, managed and distributed by different types of organisations:

- EEA or ETC/ACC
- Eurostat
- National environment agencies or ministries
- National statistical agencies
- Universities or other research institutions.

8.2 Data availability and accessibility

The following chapter gives an overview of the availability and accessibility of input data. It assesses the technical access, the time necessary to obtain data as well as the restrictions and costs.

8.2.1 Concentration data

Air quality concentration data comprise monitoring and model data on different spatial scales. Table 79 summarises the data sources and the accessibility of these data.

Table 79: Overview of data sources for concentrations.

Data type	Reference area	data provider	Technical access	Temporal resolution	Access
AQ monitoring data	EEA area	AirBase (ETC-ACC)	internet	days	free
AQ monitoring data	Austria	Umweltbundesamt		hours	free
AQ model data Klagenfurt	Klagenfurt (town)	Technical University Graz	e-mail by data provider	days	on request
AQ model data Rijnmond	Rijnmond area	TNO	e-mail by data provider	weeks	on request
AQ model data England	England	AEAT	e-mail by data provider	weeks	on request
AQ model data EMEP	EMEP model domain	EMEP	internet	minutes	free

Validated monitoring data are easily accessible throughout Europe.

The limitations of accessing model data are related to their specific application. Model data are usually not provided for public information as monitoring data but – in most cases – as policy support (scenarios for AQ management plans). They are, in many cases, not administered by public bodies but scientific institutions. Data are often produced for specific applications and specific customers and therefore access may be limited.

8.2.2 Emission data

Emission inventory data (Table 80) are usually not freely available (e.g. on the internet), but have to be requested from the data provider.

The difficulty of handling emission inventory data arises from the necessity of data visualisation and analysis using geographical information systems.

For the present study, TeleAtlas data were available for Austria only. The acquisition of the TeleAtlas road data on other countries would have been very costly.

Table 80: Overview of data sources for emissions.

Data type	Reference area	data provider	Technical access	Time	Access
Emission inventory Wien	Wien	Municipal administration Wien	e-mail	days	on request
Emission inventory Oberösterreich	Oberösterreich	Provincial administration Oberösterreich	e-mail	days	on request
Emission inventory Klagenfurt	Klagenfurt	Technical University Graz	e-mail	days	on request
Emission inventory Rijnmond	Rijnmond area	TNO	e-mail	weeks	on request
TeleAtlas road map	Europe	TeleAtlas			very costly

8.2.3 Information on the dispersion situation

The dispersion situation (see Table 81) can be derived from various data sources on different scales. Electronic information which allows quantitative analysis is rare.

Table 81: Overview of the data sources for the dispersion situation.

Data type	Reference area	data provider	Technical access	Time	Access
„Multipurpose map" Wien	Wien	Municipal administration Wien	e-mail	days	very costly, on request
CORINE Landcover	Europe		available at Umweltbundesamt		
Topographic map	Austria	Bundesamt für Eich- und Vermessungswesen	available at Umweltbundesamt		

8.2.4 Other data

Unlike air quality and topographic data, basic population data and data on traffic volume are more easily available. For the present study, these data were available from the national statistical office and highway authority.

Recently, the European Commission has started work to develop the GMES Atmospheric Core Service, in which air quality data from satellites and ground-based stations will be used and synthesised within different service products, and provided to a variety of users. A key requirement for this integration is that the spatial representativeness of the monitoring stations in Europe is well defined. This proposal, aiming to improve the classification of stations and the deliniation of the area of representativeness, is intended to support the development of the service.

8.3 Applicability of the proposed methods

The applicability of the proposed methods for the classification of monitoring stations and the assessment of their representative areas are highly dependent on the availability and quality of input data, as well as on the expertise of people performing the relevant tasks. For experienced air quality managers, the proposed methods present no difficulties. The availability of data may be more difficult in most cases.

8.3.1 Classification

The chapters dealing with the testing of the classification method (chapter 6) and the validation of the method for the assessment of representativeness (chapter 7) compare different approaches using different input data sets and point out the limitations of these approaches.

In general, for a solid application of the classification method proposed, fairly accurate emission data from road traffic at each single major road and from domestic heating on a spatial resolution of 1 km are necessary. In addition, a fairly accurate assessment of the impact of industrial emissions is required.

Emission data should be retrieved from an emission inventory with sufficient spatial resolution. Average emission factors can be quite misleading, especially in the case of PM10 emissions per capita from domestic heating, which vary by a factor of 10 depending on fuel use and heating structure. But also road traffic emission factors strongly depend on the traffic situation, with large differences between e.g. urban and highway situations.

The impact of industrial emissions, especially in case of large point sources, should be assessed by modelling.

8.3.2 Representativeness

The assessment of representativeness requires even more input data and the combination of concentrations, emissions and information on the dispersion situation on different scales.

Data of sufficient accuracy and spatial resolution are not easily available in most of Europe. The optimum set of input data is summarised in Table 82.

These data are considered necessary for the assessment of the representative area of urban monitoring stations, especially detailed information about the building structure.

Table 82: Optimum input data for the assessment of the representative area.

Spatial information on the pollutant concentration	Model with resolution of 10 m (thus resolving streets)
Spatial information on emissions from road traffic and domestic heating	Emission inventory: resolution of areal sources at least 1 km; representation of major roads
Information on the impact from industrial emissions	Model with resolution of 1 km at least
Spatial information about street geometry and building structure	High resolution map representing each building, or, at least, each block
Spatial information about the regional dispersion situation	Topographic map on a scale 1:100,000 or better

As these data are not easily available, surrogate data can be used to estimate or parameterise concentrations, emissions and local dispersion situation. Table 83 lists the simplest set of surrogate data, which are used for the assessment of representative areas in chapter 7.2.6. A more sophisticated approach could, for example, be based on parameterisations like WEBER (2003).

Table 83: Surrogate input data for the assessment of the representative area.

Spatial information on the pollutant concentration	CORINE Landcover TeleAtlas Population distribution
Spatial information on emissions from road traffic and domestic heating	CORINE Landcover TeleAtlas Population distribution
Information on the impact from industrial emissions	CORINE Landcover
Spatial information about street geometry and building structure	CORINE Landcover
Spatial information about regional dispersion situation	Topographic map

8.4 Availability of data for this study

The scope of this study was to develop and validate methods for the classification of monitoring stations and for the assessment of their representativeness based upon data from different regions in Europe, covering different types of stations with respect to topography and climate. The original idea was to use data from Austria, which are easily accessible by the Umweltbundesamt in Wien, from north-western Europe (flat terrain, oceanic climate) and from a Mediterranean region.

As the study clearly shows, the broad majority of monitoring stations and cases for test and validation are Austrian ones. During the study it turned out that a multitude of data are necessary and that retrieving these data from different data providers provides several challenges:

- the necessity of several communication steps to specifiy what kind of data is exactly required is very time consuming
- investigation of errors, obtaining of missing data and the discussion of open questions is very time consuming
- data from different sources/providers have to be combined: air quality measurement, model results, emissions, land use, etc.

In the case of southern France – which was envisaged as a region for the evaluation – no reply from the data provider was received in time to include the data in the validation.

The fact that different types of input data are readily available at the Umweltbundesamt, especially concerning GIS based data – CORINE Landcover, TeleAtlas, topographic maps – made the use of these data sets for validation quite comfortable.

9 GLOSSARY

AOT40	Accumulated exposure over threshold (of 40 ppb)
AQ	Air Quality
AQD	Air Quality Directives
EC	European Community
EEA	European Environment Agency
EoI	Exchange of Information
ETC-ACC	European Topic Centre for Air and Climate Change
FWD	Air Quality Framework Directive (96/62/EC)
FRC	Functional Road Classes
HDV	Heavy duty vehicle
JRC	Joint Research Centre
NO	Nitrogen monoxide
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
PAH	Polycyclic aromatic hydrocarbons
PM	Particulate matter
PM10	Particulate matter with aerodynamic size < 10 µm
SO_2	Sulphur dioxide
Umweltbundesamt	Environment Agency

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ANNEX

Test of Classification

Table 84: Comparison of the EoI station type with the classification according to local road traffic, domestic heating and industrial emissions of NO_x and PM10.

P[28]	Station	EoI Station	NO_x Traffic	PM10 Traffic	NO_x Domestic	PM10 Domestic	NO_x Industrial	PM10 Industrial
B	Eisenstadt	Traffic	low	medium	medium	medium	low	low
B	Illmitz	Background	low	low	low	low	low	low
B	Kittsee	Industrial	low	low	low	low	low	medium
B	Oberwart – Brunnenfeld	Background	low	low	low	low	low	low
K	Arnoldstein Gailitz	Industrial	low	low	low	high	low	low
K	Bleiburg Koschatstrasse	Background	low	low	low	high	low	low
K	Gerlitzen Steinturm	Background	low	low	low	low	low	low
K	Klagenfurt Koschatstrasse	Background	low	medium	medium	medium	low	low
K	Klagenfurt Kreuzbergl	Background	low	low	low	medium	low	low
K	Klagenfurt Völkermarkter Str.	Traffic	medium	high	medium	medium	medium	medium
K	Oberdrauburg Bundesstrasse	Traffic	low	low	low	low	low	low
K	Obervellach Schulzentrum	Background	low	low	low	low	low	low
K	Soboth Forsthaus	Background	low	low	low	low	low	low
K	Spittal a.d.Drau Oktoberstrasse	Background	low	low	medium	high	low	low
K	St. Andrä i.L. Volksschule	Traffic	medium	medium	medium	medium	low	low
K	St. Georgen im Lavanttal	Background	low	low	low	low	low	low
K	St. Veit a.d.Glan Oktoberplatz	Traffic	low	low	medium	medium	low	low
K	Villach Tirolerbrücke	Traffic	medium	medium	medium	medium	low	low
K	Vorhegg	Background	low	low	low	low	low	low
K	Wietersdorf Pemberg	Industrial	low	low	low	low	medium	medium
K	Wolfsberg Hauptschule	Traffic	low	medium	medium	medium	low	medium
N	Amstetten	Background	low	medium	medium	medium	low	medium
N	Annaberg – Joachimsberg	Background	low	low	low	low	low	low
N	Bad Vöslau – Gainfarn	Background	low	low	low	medium	low	low
N	Brunn am Gebirge	Background	medium	medium	medium	medium	low	low
N	Dunkelsteinerwald	Background	low	low	low	low	low	low
N	Forsthof am Schöpfl	Background	low	low	low	low	low	low
N	Gänserndorf	Background	low	low	low	medium	low	low
N	Großenzersdorf – Glinzendorf	Background	low	low	low	low	low	low
N	Hainburg	Background	low	low	low	medium	low	low
N	Heidenreichstein	Background	low	low	low	low	low	low
N	Himberg	Background	low	low	low	medium	low	low
N	Irnfritz	Background	low	low	low	low	low	low
N	Klosterneuburg Wiesentgasse	Background	low	low	medium	medium	low	low
N	Kollmitzberg	Background	low	low	low	low	low	low
N	Krems	Background	low	low	medium	medium	low	low
N	Mannswörth bei Schwechat	Industrial	low	low	low	low	low	medium
N	Mistelbach	Background	low	low	medium	medium	low	low
N	Mödling	Background	low	low	high	medium	low	low
N	Neusiedl im Tullnerfeld	Industrial	low	low	low	low	low	low
N	Payerbach – Kreuzberg	Background	low	low	low	low	low	low
N	Pillersdorf bei Retz	Background	low	low	low	low	low	low
N	Pöchlarn	Background	low	low	low	medium	low	low
N	Purkersdorf	Background	low	low	low	medium	low	low
N	Schwechat	Background	low	low	medium	medium	medium	medium

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[28] Federal Province

P[28]	Station	EoI Station	NO_x Traffic	PM10 Traffic	NO_x Domestic	PM10 Domestic	NO_x Industrial	PM10 Industrial
N	St. Pölten Europaplatz	Traffic	medium	high	medium	high	low	low
N	St. Pölten Eybnerstrasse	Industrial	low	low	medium	high	low	low
N	St. Valentin – Westautobahn	Traffic	high	high	low	low	low	low
N	Stixneusiedl	Background	low	low	low	low	low	low
N	Stockerau West	Traffic	medium	medium	low	medium	low	low
N	Streithofen	Background	low	low	low	low	low	low
N	Ternitz	Background	low	low	medium	medium	low	low
N	Traismauer	Background	low	low	low	medium	low	low
N	Trasdorf	Industrial	low	low	low	low	low	low
N	Tulbinger Kogel	Background	low	low	low	low	low	low
N	Tulln – Wilhelmstraße	Traffic	low	low	medium	medium	low	low
N	Vösendorf	Traffic	medium	medium	low	medium	low	low
N	Waidhofen an der Ybbs	Background	low	low	low	medium	low	low
N	Wiener Neustadt	Background	low	low	low	medium	low	low
N	Wiesmath	Background	low	low	low	low	low	low
N	Wolkersdorf	Background	low	low	low	medium	low	low
N	Ziersdorf	Background	low	low	low	low	low	low
N	Zwentendorf	Industrial	low	low	low	low	low	low
O	Bad Ischl	Background	low	low	low	medium	low	low
O	Braunau Zentrum	Traffic	low	medium	medium	medium	low	low
O	Enns Kristein A1	Traffic	high	high	low	low	low	low
O	Enzenkirchen im Sauwald	Background	low	low	low	low	low	low
O	Grünbach bei Freistadt	Background	low	low	low	low	low	low
O	Lenzing	Industrial	low	low	low	medium	low	low
O	Linz 24er Turm	Traffic	medium	medium	medium	medium	low	medium
O	Linz Kleinmünchen	Background	medium	medium	medium	medium	low	medium
O	Linz Neue Welt	Industrial	medium	high	medium	medium	medium	high
O	Linz ORF-Zentrum	Industrial	medium	medium	high	high	medium	high
O	Linz Römerbergtunnel	Traffic	medium	high	medium	medium	low	medium
O	Linz Urfahr	Traffic	medium	medium	medium	medium	low	medium
O	Schöneben	Background	low	low	low	low	low	low
O	Steyr	Background	low	low	low	medium	low	low
O	Steyregg Weih	Industrial	low	low	low	medium	medium	medium
O	Traun	Background	low	low	medium	medium	low	low
O	Vöcklabruck	Background	low	low	medium	medium	low	low
O	Wels Linzerstraße	Traffic	medium	medium	medium	medium	low	low
O	Zöbelboden	Background	low	low	low	low	low	low
S	Hallein A10 Tauernautobahn	Traffic	high	high	low	low	low	low
S	Hallein Hagerkreuzung	Traffic	high	high	medium	medium	medium	low
S	Hallein Winterstall	Background	low	low	low	low	low	low
S	Haunsberg	Background	low	low	low	low	low	low
S	Salzburg	Background	low	medium	medium	medium	low	low
S	Salzburg Mirabellplatz	Traffic	medium	medium	medium	medium	low	low
S	Salzburg Rudolfsplatz	Traffic	high	high	medium	medium	low	low
S	Sonnblick	Background	low	low	low	low	low	low
S	St. Johann im Pongau BH	Background	low	low	medium	medium	low	low
S	St. Koloman Kleinhorn	Background	low	low	low	low	low	low
S	Tamsweg Untere Postgasse	Background	low	low	medium	high	low	low
S	Zederhaus	Traffic	medium	medium	low	low	low	low
S	Zell am See Krankenhaus	Background	low	low	low	low	low	low
St	Arnfels – Remschnigg	Background	low	low	low	low	low	low
St	Bockberg	Background	low	low	low	low	low	low
St	Bruck an der Mur	Traffic	low	low	medium	medium	low	low
St	Deutschlandsberg	Background	low	low	medium	high	low	low
St	Gratwein	Industrial	low	low	low	medium	medium	medium
St	Graz Don Bosco	Traffic	high	high	medium	medium	low	low
St	Graz Mitte	Background	low	low	high	high	low	low
St	Graz Nord	Background	low	low	medium	medium	low	low
St	Graz Ost Petersgasse	Traffic	low	medium	medium	medium	low	low

P[28]	Station	EoI Station	NO_x Traffic	PM10 Traffic	NO_x Domestic	PM10 Domestic	NO_x Industrial	PM10 Industrial
St	Graz Platte	Background	low	low	low	low	low	low
St	Graz Schloßberg	Background	low	low	medium	medium	low	low
St	Graz Süd Tiergartenweg	Background	low	medium	medium	medium	medium	medium
St	Graz West	Background	low	medium	medium	medium	low	low
St	Grundlsee	Background	low	low	low	low	low	low
St	Hartberg	Background	low	low	medium	high	low	low
St	Hochgössnitz	Background	low	low	low	low	low	low
St	Hochwurzen	Background	low	low	low	low	low	low
St	Judenburg	Background	low	low	medium	medium	low	low
St	Judendorf Süd	Industrial	low	low	low	medium	low	low
St	Kapfenberg	Background	low	medium	medium	medium	low	low
St	Klöch bei Bad Radkersburg	Background	low	low	low	low	low	low
St	Knittelfeld Parkstraße	Background	low	low	medium	medium	low	low
St	Köflach	Background	low	low	medium	medium	low	low
St	Leoben Donawitz	Industrial	low	low	medium	medium	low	medium
St	Leoben Göss	Background	low	medium	medium	medium	low	low
St	Leoben Zentrum	Background	low	low	medium	medium	low	low
St	Liezen	Background	low	medium	medium	high	low	low
St	Masenberg	Background	low	low	low	low	low	low
St	Mürzzuschlag Roseggerpark	Background	low	low	medium	high	low	low
St	Niklasdorf	Background	low	low	low	medium	low	low
St	Peggau	Industrial	low	low	low	medium	low	low
St	Piber	Background	low	low	low	medium	low	low
St	Pöls Ost – Unterer Zechner	Industrial	low	low	low	low	low	low
St	Rennfeld	Background	low	low	low	low	low	low
St	Stolzalpe bei Murau	Background	low	low	low	low	low	low
St	Straßengel Kirche	Industrial	low	low	low	medium	low	low
St	Voitsberg Krems	Background	low	low	low	medium	low	low
St	Voitsberg Mühlgasse	Background	low	low	medium	medium	low	low
St	Weiz	Background	low	low	medium	high	low	low
St	Zeltweg	Background	low	low	medium	high	low	low
T	Brixlegg Innweg	Industrial	medium	medium	low	medium	low	medium
T	Gärberbach A13	Traffic	high	high	low	high	low	low
T	Hall i.T. Münzergasse	Traffic	medium	medium	medium	high	low	low
T	Heiterwang Ort - B179	Traffic	medium	medium	low	low	low	low
T	Höfen Lärchbichl	Background	low	low	low	low	low	low
T	Imst Imsterau	Traffic	medium	high	low	low	low	medium
T	Innsbruck Reichenau	Traffic	medium	high	high	high	low	low
T	Innsbruck Sadrach	Background	low	low	medium	medium	low	low
T	Innsbruck Zentrum	Traffic	medium	medium	medium	medium	low	low
T	Karwendel West	Background	low	low	low	low	low	low
T	Kramsach Angerberg	Background	low	low	low	low	low	low
T	Kufstein Festung	Background	low	low	medium	medium	low	low
T	Kufstein Praxmarerstraße	Background	medium	medium	medium	high	low	low
T	Lienz Amlacherkreuzung	Traffic	high	high	medium	high	low	low
T	Lienz Sportzentrum	Background	low	low	medium	medium	low	low
T	Nordkette (Seegrube)	Background	low	low	low	low	low	low
T	St. Sigmund im Sellrain	Background	low	low	low	low	low	low
T	Vomp – An der Leiten	Traffic	high	medium	medium	high	low	low
T	Vomp A12 (Inntalautobahn)	Traffic	high	high	medium	high	low	low
T	Wörgl Stelzhamerstraße	Traffic	medium	medium	medium	medium	low	low
T	Zillertaler Alpen	Background	low	low	low	low	low	low
V	Bludenz Herrengasse	Background	low	low	medium	medium	low	low
V	Dornbirn Stadtstraße	Traffic	medium	medium	medium	medium	low	low
V	Feldkirch Bärenkreuzung	Traffic	medium	high	medium	medium	low	low
V	Höchst Gemeindeamt	Traffic	medium	medium	medium	medium	low	low
V	Lustenau Wiesenrain	Background	low	low	medium	medium	low	low
V	Lustenau Zollamt	Traffic	medium	medium	medium	medium	low	low
V	Sulzberg – Gmeind	Background	low	low	low	low	low	low

P[28]	Station	EoI Station	NO_x Traffic	PM10 Traffic	NO_x Domestic	PM10 Domestic	NO_x Industrial	PM10 Industrial
V	Wald am Arlberg	Traffic	low	low	low	low	low	low
W	Belgradplatz	Traffic	low	medium	high	high	low	low
W	Floridsdorf	Traffic	low	low	medium	medium	low	low
W	Gaudenzdorf	Traffic	medium	medium	high	high	low	low
W	Hermannskogel	Background	low	low	low	low	low	low
W	Hietzinger Kai	Traffic	high	high	high	high	low	low
W	Hohe Warte (ZAMG)	Background	low	low	high	medium	low	low
W	Kaiserebersdorf	Industrial	low	low	low	low	low	low
W	Kendlerstraße	Traffic	low	low	high	high	low	low
W	Laaer Berg	Traffic	medium	medium	high	medium	low	low
W	Liesing	Traffic	medium	medium	medium	low	low	low
W	Lobau – Grundwasserwerk	Background	low	low	low	low	low	low
W	Rinnböckstraße	Traffic	medium	medium	high	medium	low	low
W	Schafbergbad	Background	low	low	medium	medium	low	low
W	Stadlau	Background	low	low	medium	low	low	low
W	Stephansplatz	Background	low	low	high	high	low	low
W	Taborstrasse	Traffic	high	high	high	high	low	low
W	Währinger Gürtel	Background	low	low	high	high	low	low

Validation of Assessment of Representativenes

Table 85: Representativeness criteria fulfilled for Illmitz for NO_2 and PM10.

Concentration within range in all years		**Emission PM10**	**Dispersion**	
NO_2	**PM10**		**Local**	**Regional**
	Eisenstadt		built-up	ok
	Kittsee		ok	ok
	Klagenfurt Koschatstr.		built-up	basin
Obervellach			ok	valley
St. Georgen			ok	valley
Dunkelsteinerwald			ok	hills
Forsthof			ok	hills
	Glinzendorf[29], [30]	ok	ok	ok
Heidenreichstein			ok	ok
Payerbach			forest	hills
Pillersdorf	Pillersdorf[32]	ok	ok	ok
Streithofen			ok	ok
Trasdorf			ok	ok
Tulbinger Kogel			ok	hills
Waidhofen			ok	hills
Enzenkirchen			ok	hills
Grünbach			ok	hills
	Steyregg[32]		ok	hills
	Wels		built-up	ok
Zöbelboden			ok	hills
	Hallein Hagerkreuzung		built-up	valley
Haunsberg			ok	hills
	Salzburg Lehen[32]		built-up	basin
	Bruck a.d.M.		built-up	valley
	Leoben Donawitz		built-up	valley
Hochgössnitz			ok	hills
	Niklasdorf		ok	valley
Piber			ok	hills
Pöls			ok	valley
	Innsbruck Zentrum		built-up	valley
	Lienz		built-up	valley
	Wörgl		built-up	valley
Sulzberg			ok	hills
	Wien Belgradplatz[31]		built-up	ok
	Wien Floridsdorf		built-up	ok
	Wien Gaudenzdorf		built-up	ok
	Wien Kaiserebersdorf[32]		built-up	ok
	Wien Kendlerstraße[32]		built-up	ok
	Wien Laaerberg[32]		built-up	ok
	Wien Schafbergbad		built-up	hills

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[29] only data for 2004 and 2005.

[30] possible underestimation at most sites in Niederösterreich due to too low correction factor

[31] possible underestimation due to trees around the monitoring sites.

Table 86: Representativeness criteria fulfilled for Eisenstadt for NO_2 and PM10.

Concentration within range in all years		**Emission**		**Dispersion**	
NO_2	**PM10**	**NO_x**	**PM10**	**Local**	**Regional**
	Illmitz			open terrain	ok
Kittsee	Kittsee			open terrain	ok
	Oberwart			open terrain	ok
Arnoldstein				open terrain	basin
Wietersdorf				open terrain	hills
	Villach		ok	ok	basin
	Amstetten			ok	ok
	Glinzendorf[32], [33]			open terrain	ok
Klosterneuburg		ok		ok	ok
Krems		ok		open terrain	ok
Mödling				ok	ok
	Pillersdorf[32]			open terrain	ok
Pöchlarn				open terrain	ok
Purkersdorf				ok	valley
St. Pölten Eybnerstr.		ok		open terrain	ok
St. Valentin Stein				open terrain	ok
Stockerau			ok	open terrain	ok
Traismauer				open terrain	ok
Wiener Neustadt				open terrain	ok
Bad Ischl				ok	valley
Braunau		ok		ok	ok
	Enns A1			open terrain	ok
Lenzing				open terrain	valley
	Linz 24er Turm			open terrain	ok
Steyr				ok	ok
Steyregg	Steyregg			open terrain	hills
	Traun			ok	ok
Vöcklabruck		ok		ok	valley
	Wels		ok	ok	ok
Hallein Winterstall				open terrain	hills
Bruck a.d.M.	Bruck a.d.M.	ok		ok	valley
Deutschlandsberg		ok		ok	hills
Gratwein	Gratwein			open terrain	valley
Hartberg		ok		ok	hills
Judenburg		ok		open terrain	valley
Kapfenberg		ok	ok	open terrain	valley
Knittelfeld		ok		ok	valley
Leoben Donawitz	Leoben Donawitz	ok		ok	valley
Leoben Zentrum		ok		ok	valley
Liezen		ok		ok	valley
Niklasdorf				open terrain	valley
Voitsberg Mühlgasse		ok		ok	valley
Zeltweg		ok		ok	valley
	Innsbruck Zentrum		ok	street canyon	valley
	Lienz			ok	valley
	Vomp A12			open terrain	valley
	Wien Belgradplatz			ok	ok
	Wien Floridsdorf			ok	ok
	Wien Gaudenzdorf			ok	ok
	Wien Kaiserebersdorf[32]			ok	ok
	Wien Kendlerstr.[32]			ok	ok
	Wien Laaerberg[32]		ok	ok	ok
Wien Schafbergbad		ok		ok	hills

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[32] only data from 2004 and 2005

[33] possible underestimation due to too low correction factor in the monitoring network Niederösterreich.

Table 87: Representativeness criteria fulfilled for St. Pölten Eybnerstraße for NO_2 and PM10.

Concentration within range in all years		**Emission**		**Dispersion**	
NO_2	**PM10**	**NO_x**	**PM10**	**Local**	**Regional**
Eisenstadt		ok			ok
Klagenfurt Koschatstr.		ok			
Spittal		ok	ok		
	Villach				
Amstetten		ok			ok
	Brunn a.G.[34]				ok
	Glinzendorf			ok	ok
	Hainburg			ok	ok
	Himberg				ok
	Klosterneuburg	ok			ok
Krems		ok		ok	ok
	Mistelbach	ok		ok	ok
Mödling	Mödling				ok
	Pillersdorf			ok	ok
	Pöchlarn			ok	ok
Purkersdorf	Purkersdorf				
Schwechat	Schwechat			ok	ok
St. Valentin Stein				ok	ok
Stockerau	Stockerau			ok	ok
Wiener Neustadt	Wiener Neustadt			ok	ok
Braunau	Braunau	ok			ok
Steyr					ok
Steyregg				ok	
Bruck a.d.M.		ok			
	Deutschlandsberg	ok	ok		
Graz Nord		ok			
Judendorf				ok	
Knittelfeld		ok			
Köflach		ok			
Leoben Zentrum		ok			
Peggau					
Straßengel					
Voitsberg Krems					
Weiz		ok	ok		
Zeltweg		ok	ok		
Heiterwang					
Kramsach					
	Vomp a.d.L.				
	Vomp A12				
Bludenz		ok			
	Höchst				
Lustenau Wiesenrain	Lustenau Wiesenrain	ok			
	Wien Floridsdorf	ok			ok
Wien Hohe Warte					
	Wien Kaiserebersdorf				ok
	Wien Kendlerstr.				ok
	Wien Laaerberg				ok
Wien Stadlau		ok			ok

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[34] possible underestimation due to too low correction factor.

Table 88: Representativeness criteria fulfilled for Wien Belgradplatz for NO_2 and PM10.

Concentration within range in all years		**Emission**		**Dispersion**	
NO_2	**PM10**	**NO_x**	**PM10**	**Local**	**Regional**
	Eisenstadt			ok	ok
	Illmitz				ok
	Kittsee				ok
	Villach			ok	
	Amstetten			ok	ok
	Großenzersdorf				ok
	Pillersdorf				ok
St. Pölten Europapl.				ok	ok
	Enns				ok
Linz 24er Turm	Linz 24er Turm				ok
Linz Neue Welt	Linz Neue Welt			ok	ok
Linz ORF-Zentrum	Linz ORF-Zentrum			ok	ok
Linz Urfahr				ok	ok
	Steyregg				
	Traun			ok	ok
	Hallein Hagerkreuzung			ok	
Salzburg Lehen				ok	
Salzburg Mirabellpl.				ok	
Zederhaus					
	Bruck a.d.M.			ok	
	Deutschlandsberg			ok	
Graz Süd				ok	
	Gratwein				
	Graz Nord			ok	
	Knittelfeld			ok	
	Leoben Donawitz				
	Brixlegg			ok	
	Hall i.T.		ok	ok	
	Innsbruck Reichenau			ok	
Kufstein Praxmaerstr.				ok	
Lienz Amlacherkreuzung				ok	
	Vomp A12				
Dornbirn	Dornbirn			ok	
	Feldkirch				
Wien Floridsdorf	Wien Floridsdorf	ok		ok	ok
Wien Gaudenzdorf	Wien Gaudenzdorf		ok	ok	ok
	Wien Kaiserebersdorf			ok	ok
	Wien Kendlerstr.			ok	ok
	Wien Laaerberg			ok	ok
	Wien Liesing			ok	ok
	Wien Stadlau			ok	ok
Wien Währinger Gürtel	Wien Währinger Gürtel	ok		ok	ok

Table 89: Representativeness criteria fulfilled for Illmitz for Ozone.

Concentration within range for all years	**Ozone formation**	**Exposure**	**Regional dispersion situation**
Kittsee	ok	ok	ok
Oberwart		ok	ok
Gerlitzen			
Vorhegg			
Amstetten			ok
Annaberg			
Bad Vöslau	ok	ok	ok
Dunkelsteinerwald	ok		
Forsthof	ok		
Gänserndorf	ok	ok	ok
Glinzendorf	ok	ok	ok
Hainburg	ok	ok	ok
Himberg	ok	ok	ok
Irnfritz	ok	ok	ok
Klosterneuburg	ok		ok
Mistelbach	ok	ok	ok
Mödling	ok	ok	ok
Pillersdorf	ok	ok	ok
Pöchlarn	ok	ok	ok
Purkersdorf	ok	ok	
Schwechat	ok	ok	ok
Stixneusiedl	ok	ok	ok
Wiener Neustadt	ok	ok	ok
Ziersdorf	ok	ok	ok
Enzenkirchen		ok	
Grünbach			
Lenzing		ok	
Schöneben			
Steyregg			
Zöbelboden			
Hallein Winterstall			
Haunsberg			
Sonnblick			
St. Koloman			
Arnfels			
Bockberg			
Graz Nord		ok	
Grundlsee			
Hochgössnitz			
Hochwurzen			
Klöch			
Piber			
Innsbruck Sadrach			
Karwendel West			
Kufstein Festung			
Nordkette			
Zillertaler Alpen			
Wien Hermannskogel	ok		
Wien Lobau	ok	ok	ok

Table 90: Representativeness criteria fulfilled for Annaberg for Ozone.

Concentration within range for all years	Ozone formation	Exposure	Regional dispersion situation
Illmitz		ok	
Kittsee		ok	
Oberwart	ok	ok	
Vorhegg	ok	ok	ok
Amstetten	ok	ok	
Bad Vöslau		ok	
Dunkelsteinerwald		ok	
Forsthof		ok	ok
Gänserndorf		ok	
Glinzendorf		ok	
Hainburg		ok	
Heidenreichstein	ok	ok	
Himberg		ok	
Irnfritz		ok	
Klosterneuburg		ok	
Mistelbach		ok	
Mödling		ok	
Pillersdorf		ok	
Pöchlarn		ok	
Purkersdorf			
Schwechat		ok	
Stixneusiedl		ok	
Vösendorf		ok	
Waidhofen	ok	ok	ok
Wiener Neustadt		ok	
Ziersdorf		ok	
Braunau	ok	ok	
Enzenkirchen	ok	ok	
Grünbach	ok	ok	ok
Lenzing	ok	ok	
Schöneben	ok	ok	ok
Steyregg	ok	ok	ok
Traun	ok	ok	
Zöbelboden	ok	ok	ok
Haunsberg	ok	ok	ok
Sonnblick	ok	ok	
St. Koloman	ok	ok	ok
Graz Nord	ok	ok	
Grundlsee	ok	ok	ok
Hochgössnitz	ok	ok	ok
Hochwurzen	ok	ok	
Klöch	ok	ok	ok
Höfen	ok	ok	
Innsbruck Sadrach	ok	ok	ok
Karwendel West	ok	ok	
Kufstein Festung	ok	ok	ok
Zillertaler Alpen	ok	ok	
Wien Lobau		ok	