UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

COMMITTEE ON ENVIRONMENTAL POLICY

Working Group on Environmental Monitoring and Assessment
in cooperation with the Executive Body for the Convention on Long-range Transboundary Air Pollution and the European Environment Agency

WORKSHOP ON INTERACTION BETWEEN AIR-QUALITY MONITORING AND AIR-PROTECTION STRATEGIES IN COUNTRIES OF EASTERN EUROPE, CAUCASUS AND CENTRAL ASIA

Geneva, 11 June 2007

REPRESENTATIVENESS AND CLASSIFICATION OF AIR QUALITY MONITORING STATIONS[1]

1. Concept and Objectives

The main objectives of the EU 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 monitoring sites for various pollutants (focussing on NO_2, PM10/PM2,5 and Ozone, but also taking into account SO_2, NOx, CO, benzene, etc.);
- the assessment 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 for different pollutants;
- 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 several years in fact means 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.

[1] Prepared by Mr. Wolfgang Spangl, Federal Environment Agency, Austria under Service Contract to the European Commission, DG ENV, Reference: ENV.C.1/SER/2005/0064r. The document has not been formally edited.

2. 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.
Classification of AQ monitoring stations creates groups of monitoring sites with common characteristics, providing the following information:

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

The classification scheme developed 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 large sea harbours).

The classification scheme can be applied for primarily emitted pollutants and is, of course, specific for each pollutant.
This classification scheme is similar to the "type of station" classification in the EoI meta-data (97/01/EC).

The classification scheme is based upon the **absolute contribution of each source category** to the concentration level observed at the monitoring station. The assessment of the relative contribution of different sources or source categories can be achieved by various methods, of which modelling may be the most comprehensive and accurate way, but also the most expensive. 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 classification scheme does not cover emissions from the following sectors: off-road machinery, agriculture, natural PM sources, as the quantification and spatial allocation of these emissions is very difficult. These sources are also less relevant in general.

The classification parameter for **local road traffic** is the potential contribution from local road traffic to the measured concentration. "Local" road traffic has to be taken into account, since total road traffic on a wider spatial scale (which contributes e.g. a predominant share to total urban NOx emissions) also influences the measured concentrations by its contribution to the background concentration.

The classification method discussed in this study can be applied in the case that modelling is not available. The contribution of road traffic emissions is named "traffic parameter" and is quantified by the following approximation:

Traffic parameter = **emissions or 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. It underestimates the real concentration distribution near the street and overestimates it at larger distances.

The distance has to be taken from the kerb of the road to the air inlet. For highways, the distance from the kerb of the first traffic lane (not the breakdown lane or the shoulder) has to be taken.

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 affected by traffic emissions (or only to a minor extent). Based on model results, a "shielding" or "exposure coefficient" is introduced, which is multiplied with the respective traffic emissions. The exposure coefficient is assumed **0** for a configuration monitoring site/road with complete close building between (which means that in such cases nearby traffic emissions do not contribute for the measured pollution) and **0.5** for buildings with small gaps or a location of the monitoring site in a narrow cross lane, and **1** for all other cases.

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 surrounding of 1 km radius**.

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

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

Since **ozone** – as a totally secondary pollutant – can not be classified according to emissions, formation and depletion processes have to be used for the 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 **NOx emissions by local road traffic**; two classes are proposed;

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 due to **exposure**:

- "plane" 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.

2. **Regional photochemical ozone formation** in the plumes of large agglomerations can be assessed either by expert judgement or assessment of regional NOx and VOC emissions in a circle of approx. 50 to 100 km; 2 classes are proposed.

The **classification of 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). Nevertheless, the analysis of Austrian population data and the discussion of possible classification criteria for population on different spatial scales led to a somehow different scheme.

It can be used both to exposure assessment and assessment of total emissions, since the population density is a surrogate for spatially distributed emissions. The proposed criteria are based on a combination of the population numbers in the surroundings of 1 km and 10 km radius. 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 separates the following types of areas: 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.

3. Test of the classification method using Austrian data

The classification method has been tested using NO_2, PM10 and Ozone monitoring stations in Austria and the Netherlands. For each of the three emission categories – local road traffic, domestic heating and industry – three classes have been separated. The class boundaries have been selected based upon the distribution of the classification parameter for local road traffic and domestic heating; industrial sites have been classified into the classes "low" and "medium" using model results and estimates from various sources.

Table 1 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 2 gives the cross-classification according to traffic, domestic heating and industrial emissions of NOx.

Table 1: Classification results for 182 Austrian NO_2 monitoring sites, separate presentation 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	**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 2: Cross-classification according to traffic, domestic heating and industrial emissions of NOx. 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, as well as 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.

The average NO_2 concentration shows no relation to the classification according to industrial emissions; the influence of those 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.

Comparing these classification results with the "type of station" classification according to the Exchange of Information Decision (97/101/EC) – which is in Austria done by the provincial authorities who run the monitoring networks, in cooperation with the Umweltbundesamt – shows quite good relation between "traffic stations" according to EoI and "class high" for NO_2 according to the traffic parameter developed in this study. However, mismatches occur at some rural highways, for which the traffic influence is overestimated in the EoI classification, and urban and suburban trunk roads, at which the traffic influence is underestimated in the EoI classification.

The industrial influence related to NO_2 and PM10 is overestimated widely by the EoI classification "industrial". 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 NOx and PM emissions.

4. Definition of Representativeness

Dir. 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.

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 a time resolution of 1 h; quite different methods to estimate the representative areas on such low time scales – which much higher spatial variability – would be necessary.

The task of the assessment of **representativeness** aims 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.

We will use the following general definition of representativeness based on 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 **numeric threshold values** for averages and percentiles are proposed 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. EU25 plus Romania and Bulgaria) will give the concentration boundaries listed in Table 3.

Table 3: Recommended concentration range for "representativeness".

NO_2	difference between annual mean values	10 µg/m³
PM10	difference between annual mean values	10 µg/m³
PM10	difference between annual 90.4 percentile of daily mean values	16 µg/m³
Ozone	difference between annual 93.2 percentile of daily maximum 8-hour mean values	18 µg/m³

In order to avoid "similarity by chance" in one year, but not in another year – due to e.g. inter-annual variations of meteorological conditions – the criterion has to be fulfilled over a few years. The length of the appropriate time period will be subject to the further development of the method and the evaluation.

For NOx (which covers a concentration range of more than 300 µgNO_2/m³), a range of 10% of the total concentration range observed in Europe is not useful. NOx is of relevance only at monitoring sites where the limit value for the protection of vegetation and ecosystems applies, which means rather remote from NOx sources and at quite low concentration levels, which exceed the limit value only in rare situations. Therefore it is proposed to use the same range for **NOx** as for NO_2.

Generally it has to be kept in mind the numeric values for the thresholds used for the 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.

The 2nd criterion – "similarity due to common reasons" – is a proposed element of the definition, since similar annual mean values or percentiles can be observed by chance at different locations due to the 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 the delimitation of the area of representativeness:

- **emissions** from different types of sources (related to the classification scheme),
- **climatic and topographic dispersion conditions** including local building structure,
- a **maximum extension** of the area of representativeness, related to transport and chemical transformation in the atmosphere.

Dispersion conditions in this context are related to the topographic/geographic situation and the local building structure/street geometry which trigger the dispersion/accumulation of pollutants. They cover various scales:

Local environment	<100 m	Street geometry, local building structure and topographic situation, forest
Regional environment	<10 km	Valleys, basins, planes, coastal areas, ……
Large-scale	>10 km	Large-scale topographic and climatic region

We propose to separate the following types of "local environment" for kerb side locations (and perhaps for industrial locations), at which the dispersion of local emissions is a key factor for the local pollution level: Street canyon; one-sided compact buildings; detached buildings; flat terrain; exposed location. For background sites, a separation of built-up and flat terrain is considered

sufficient. For the "regional environment", different types of plane, 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 Plane, the Bohemian Massif, or the German Mittelgebirge.

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 less than one day (average atmospheric lifetime of about 12 h for NO_2) 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 the analysis of backward trajectories.

5. Assessment of Representativeness

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 themselves are available spatially. The assessment of the concentration distribution based on surrogate data, often called parameterisation, can be, in fact, addressed as a simple modelling technique.

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.

Obviously, these data are also input for modelling.

There have been different methods 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 the emissions. The test and validation in the study use a simple empirical relation between measured concentrations and basic geographical information

- Topography
- 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.

6. Validation of the assessment of representativeness

For the validation of the method for representativeness assessment, monitoring stations and model results from Austria, the Netherlands and England have been used. The most thorough validation was possible for Austria, since input data were most easily available.

As an example, the area of representativeness for Ozone for the rural site Annaberg (900 m) may be delimited according to the large-scale topographic region "Northern Alps", or by a circle of 100 km around the monitoring site. The area of representativeness covers, in any case, rural areas in elevated, but not high alpine terrain.

Table 4: Criteria for the delimitation of the representativeness area for Annaberg, Ozone.

Large-scale delimitation	Northern Alps in a circle of 100 km radius
Regional dispersion conditions	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

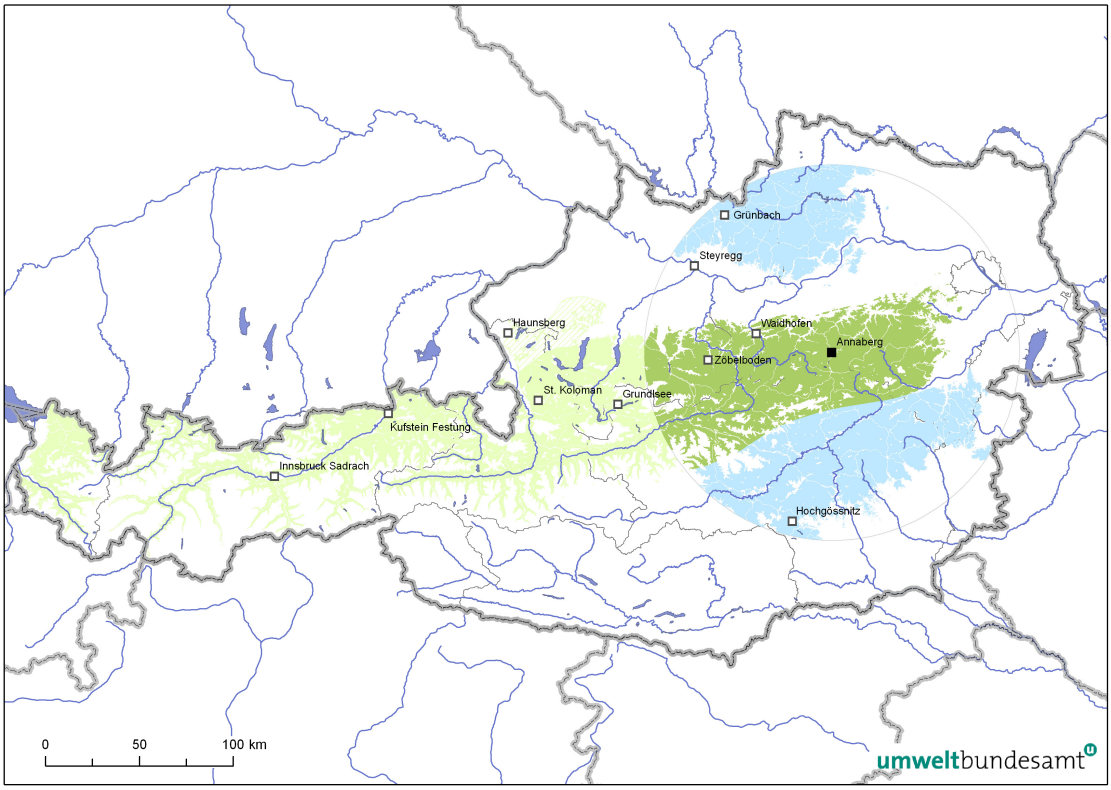

Figure 1: Area of representativeness for Annaberg, Ozone. The green area covers the large-scale topographic region "Alps north of the central Alpine ridge", the blue circle covers 100 km radius around Annaberg. Areas with absolute altitude below 500 m or above 1500 m are excluded.

For the city of Klagenfurt (90.000 inh.), model results at high resolution for NOx and PM10 are available. The model data enable a detailed delimitation of the area fulfilling the concentration criterion related to the two monitoring stations Koschatstraße and Völkermarkterstraße. As a surrogate information both for 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 2 is based upon the combination of the areas fulfilling the concentration criterion and the CLC class 1.1.2.

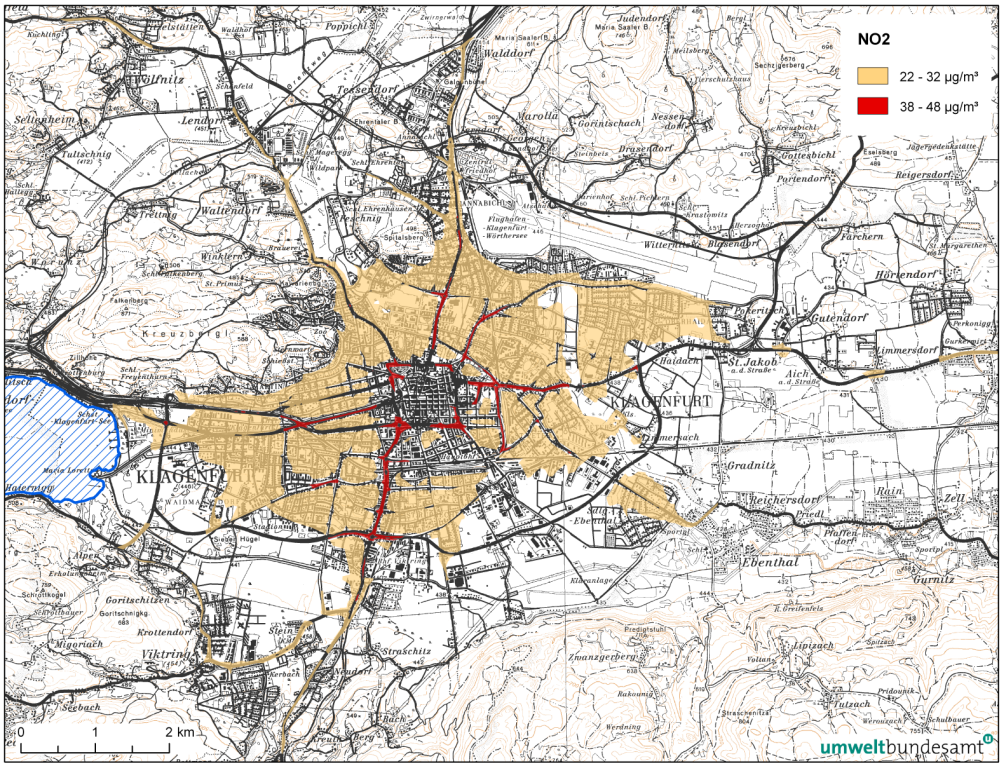

Figure 2: Approximate areas of representativeness of the monitoring sites Klagenfurt Koschatstraße (yellow) and Völkermarkterstraße (red) for NO_2.