

Air Quality Assessment Requirements Under The New EU Air Quality Directives

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Introduction

In the last few years the European Union has developed new EU air quality directives, to which in the forthcoming years further directives will be added. These directives replace and extend the old ones. The new directives consist of the Framework Directive (Council Directive 96/62/EC on ambient air quality assessment and management), which defines the general legislative structure, and related Daughter Directives, which give additional specifications per pollutant. The Daughter Directives define air quality thresholds such as limit values, target values and alert thresholds, depending on the pollutant. They also prescribe minimum requirements for the assessment of air quality levels in the Member States. Currently, there are three Daughter Directives: 1999/30/EC on sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead, 2000/69/EC on benzene and carbon monoxide and 2002/3/EC on ozone.

The new air quality directives are not easy to read. This is partly due to the fact that the provisions for a pollutant are distributed over the Daughter Directive concerned and the Framework Directive. Another reason is that the perspective on the feasibility of using models for the assessment was changing after the introduction of the Framework Directive. To clarify the provisions given in the Directives and also to give more advice to Member States on how to conduct the air quality assessment, the European Commission established in 1998 a Guidance Working Group, which has drafted a Guidance report (European Commission, 2002). The present paper is largely based on this report and gives an overview with particular attention to the role of modelling in air quality assessment under the new air quality directives.

Assessment thresholds and assessment requirements

In order to prescribe the minimum requirements for the assessment, the Framework Directive has defined three assessment regimes, which are separated by the *upper assessment threshold (UAT)* and *lower assessment threshold (LAT)*. The UAT is typically set at 70-50% of a limit value, and the LAT at 60-40%. Table 1 summarizes how the highest pollution level in a zone determines the assessment requirements for that zone. See also the illustration and further explanation in the Guidance report (European Commission, 2002).

It is important to note that the highest level occurring in a zone determines the assessment regime for the *entire* zone. So a single hotspot approaching the limit value in an otherwise 'clean' agglomeration causes the strictest assessment requirements to apply to the entire agglomeration. This does, however, not imply that the assessment efforts should be evenly distributed across such a zone; they can better be focussed on the locations where air quality is not good.

When the highest levels in a zone are not below the lower assessment threshold, one or more fixed monitoring stations are required. However, other methods to supplement the monitoring information may be used as well. In fact, the Daughter Directives encourage this by reducing

Table 1. Air quality assessment and pollution levels

Maximum pollution level in agglomeration or zone	Assessment Requirements
Regime 1: Above UAT	High quality measurement is mandatory. Fewer measurements may suffice when information from other sources is also used (e.g. air quality models).
Regime 2: Between UAT and LAT	Measurement is mandatory, but fewer measurements may be needed. Fewer measurements may suffice if information from other sources is also used
Regime 3: Below LAT	
a. In agglomerations, only for pollutants for which an alert threshold has been set ⁽¹⁾	At least one measuring site is required per agglomeration, combined with modelling, objective estimation, indicative measurements ⁽²⁾ .
b. In non-agglomeration zones for all pollutants and in all types of zone for pollutants for which no alert threshold has been set	Modelling, objective estimation, and indicative measurements alone are sufficient.

⁽¹⁾ In the first Daughter Directive alert thresholds have been set for SO₂ and NO₂.

⁽²⁾ Indicative measurements are measurements using simple methods, or carried out for a restricted time. They are less accurate than continuous high quality measurement but can be used to explore air quality as a check where pollution levels are relatively low, and to supplement high quality measurement in other areas.

the minimum number of stations in the case that other, “supplementary” assessment methods such as modelling are used (see Section 2).

When the levels are below the lower assessment threshold everywhere in the zone, fixed measurements are not legally required. Methods such as models, random or diffusive sampling may be used without fixed stations. An important exception is in agglomerations; in those zones possible alert threshold exceedences of SO₂ or NO₂ have to be surveyed with at least one station.

The combined use of measurements and models

The assessment of air quality under the new air quality directives has a broader aim than previous directives: determining compliance with air quality limit values; assessing exposure; informing the public; producing emission/exposure relations to support air quality management. Member States are required to assess the air quality throughout their territory, not only where there is risk of exceedence of thresholds such as limit values.

For air quality assessment and management purposes, the Member States need to divide their territory into zones, which are in practice often areas that coincide with administrative territories like municipalities or counties. For zones where the levels are not everywhere below the assessment thresholds, the Daughter Directives specify a minimum number of monitoring stations if the assessment is solely done by measurements. However, if supplementary methods, in particular models, are used additionally, this minimum no longer applies. Models should then be used in combination with measurements to give a territory-covering description of the pollution levels. It is then left to the Member States to determine the number of stations needed, depending on the quality of the supplementary assessment.

The distinction between measurement and modelling is not as absolute as is often thought. There is no fundamental difference between assessment using measurements interpreted by common sense and assessment using models. Models may be described as mathematical formulations of one’s understanding. Figure 1 illustrates that there is an almost continuous spectrum of combinations of measurements and other assessment methods. Neither of the two

extremes (a) and (h) is useful for assessing levels throughout a zone: 100% measuring (i.e. doing measurements that are not generalised at all) gives incomplete information, while, at the other extreme, 100% modelling (i.e. applying models that have not in any sense been validated) gives unreliable information. So, a useful assessment comprises elements of both.

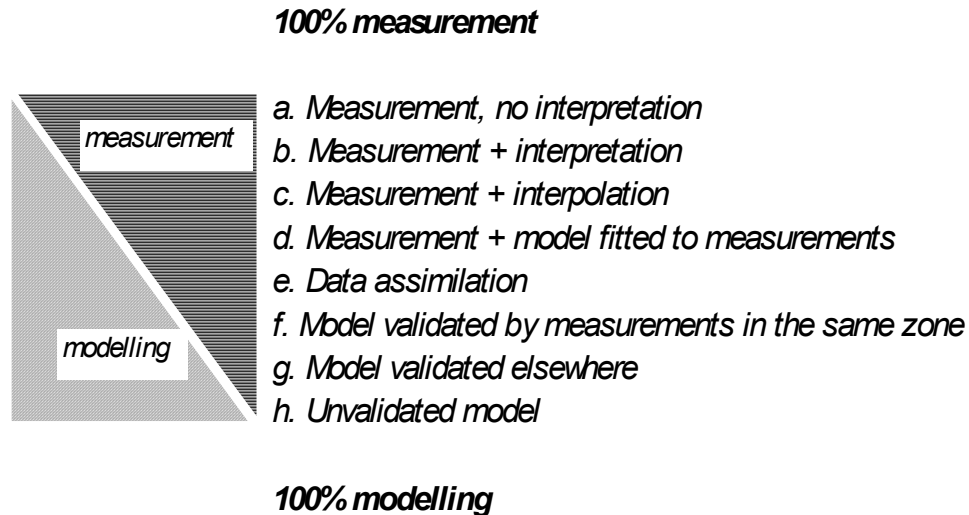


Figure 1. Combinations of measuring and modelling.

Measurement in combination with interpretation (b) has until now been the most common way of assessing the levels throughout a territory. Measurements give point-wise information, and interpretation is based on considerations of representativeness of monitoring sites.

A step further is the mathematical generalisation of measurements to give territory-covering information, such as spatial interpolation (c). This technique is useful for uniform areas with smooth air quality gradients between stations, but small-scale variations between stations cannot be identified. The interpolation can be improved by using relationships between the air pollution levels and geographical characteristics. Furthermore, for selected key-parameters (regarding source magnitude, meteorological conditions, configuration) empirical relations with air quality levels can be established. This technique uses the key-parameters for the interpolation instead of the physical distance in case of spatial interpolation. When the relationships between air quality levels and local characteristics have a fair amount of detail, they can be regarded together as constituting an empirical model (d).

A promising technique is data assimilation (e), which adjusts the values of the uncertain model parameters and measured results to find the best fit of the concentrations to the entire set of measurement and model data. The resulting map of concentration matches neither the original measurements nor the original model results, but it gives the mathematically best approximation of both.

Finally there is the sole use of validated models (f and g). Not only the reliability of the dispersion model, but also the quality of the emissions and dispersion input parameters need to be taken into account.

Currently the Member States are preparing the air quality report on 2001, their first report under the new air quality directives, which needs to be submitted before October 2002. At least several Member States are planning using both measurements and models for the

assessment. Several Member States are setting up systems for assessment for modelling and it will be interesting to see how many will have the methodologies operational in time. It seems that the majority of the model applications will not be fully integrated with the measurements. They will probably be based on models, partly fitted to measurements, but not fully integrated with measurements. There will probably be very few cases of data assimilation, if any. This is not surprising, because before data assimilation can be applied, the model uncertainty has to be well-defined – a difficult task, particularly in view of the conceptual problems that are not yet resolved (see also Section 4). Furthermore, data assimilation will change the results of measurements from the readings of the measuring device to the most probable values (within the uncertainty range of the measurement), which requires a paradigm change that will not (yet?) be accepted by many.

Some aspects of the application of models in the assessment of air quality

Spatial aspects

Spatial resolution of the limit values

In principle, models can give values for concentrations at every square metre in a zone. When concentrations determined by such techniques are compared with air quality thresholds, the spatial resolution becomes important: a high resolution tends to result in higher maximum concentrations, found at small-scale hot spots, and consequently exceedence depends on the resolution. The Daughter Directives do not specify the spatial resolution of limits values explicitly, but they do describe where stations should be sited with respect to peaks, which is a useful characterisation of the averaging area to be taken when relating model results to limit values. The spatial resolution depends on the limit value, however. For traffic-orientated situations the first Daughter Directive mentions 200 m² at traffic-orientated sites as a minimum averaging area. The first Daughter Directive does not give indications of spatial resolution for hot spots around point sources. Reasoning from the principle that every citizen should be protected, the Guidance Working Group regarded it appropriate to use a minimum resolution of approximately the size of an individual house, which is of the same order of magnitude as the 200 m² for traffic situations. For assessing exceedence of the limit values for ecosystems and vegetation the first Daughter Directive mentions an area of at least 1000 km², and areas in the vicinity of built-up areas, industrial installations or motorways should not be taken into account. These provisions can be used as a guide to choose the model resolution.

Areas where limit values are applicable

The directives do not define types of areas that need not be protected by the limit values for health. The question arises whether types of “irrelevant” areas may exist to which the limit value does not apply, e.g. pieces of wasteland. The territory-covering output of models makes this more relevant than previously: when assessing air quality solely by measurements, irrelevant locations could in practice be neglected by not placing measuring stations there, without formally deciding on the irrelevance.

The directives are ambiguous in this matter. On the one hand, the Framework Directive defines ambient air as “outdoor air in the troposphere, excluding work places”. On the other hand the first Daughter Directive relates the siting of monitoring stations to exposure. The Guidance Working Group felt that the general principles expressed by the Framework Directive are so clearly expressed that it should be concluded that the limit values apply

everywhere, except at work places. For modelling this means that high levels at locations where the population is not exposed cannot be simply disregarded.

The limit values for ecosystems and vegetation do not apply everywhere. The Directives describe this in terms of where stations should not be sited, but not so precisely that it can straightforwardly be translated to areas to be excluded on a concentration map that results from a model calculation. This poses a problem for the interpretation of concentration maps calculated by models or other mathematical methods in terms of compliance with a limit value.

Spatial and temporal requirements for models

Although the complications described above seem to be new, they are rather familiar when their analogies in the temporal domain are considered. Table 2 illustrates this for two limit values of the first Daughter Directive for SO₂. In the temporal domain, the limit value is specified in terms of coverage, resolution and percentile. In analogy the spatial provisions described above can be regarded as spatial specifications of the limit values: coverage, resolution and percentile. It is noteworthy that, implicitly, the spatial percentile of the limit value is always the maximum: it is the highest value that counts.

Table 2. Illustration of temporal and spatial aspects of limit values as defined in the new air quality directives

Temporal aspects of limit values			
Limit value SO₂	Coverage	Resolution	Statistical parameter
Health: 350 µg/m ³	Calendar year	1 hour	99.7 percentile (24 exceedences)
Ecosystems: 20 µg/m ³	(1) Calendar year; (2) winter mean	1 year	n.a.
Spatial aspects of limit values			
Limit value SO₂	Coverage	Resolution	Statistical parameter
Health: 350 µg/m ³	Entire zone, but not < 25 m from road junction and ...	About 200 m ²	Maximum ¹⁾
Ecosystems: 20 µg/m ³	Areas >20 km from agglomerations or >5 km from ...	1000 km ²	

¹⁾ The directives encourage also the calculation of the area in exceedence and population in exceedence.

These provisions cause very significant problems to modellers. A dilemma is that most of the advanced and detailed models require so much calculation time that a high spatial resolution or a full coverage of the calendar year is impossible. 3D state-of-the-art models are typically applied for only a few episodic days with a resolution of the order of a kilometre. Several solutions to this dilemma have been proposed, such as the selection of a few days that are supposed to be representative for entire year, the development of a simplified meta-model for the entire year that should represent the complex model, the possibility of adding a zooming option to a 3D model. However, all options suffer from the problem that the ideal of a comprehensive and state-of-the-art model application is approached by a surrogate method. Because of this, developers of Air Quality Management Systems need to use models that are limited in sophistication (e.g. Gaussian plume models) or need to make compromises in coverage or resolution.

Modelled exceedence and compliance with limit values

The formal use of models in air quality assessment makes it necessary to consider the

possibility that limit value exceedences are found through the use of models, particularly when measurement has an outcome different from the results of a model. Even if the model gave reliable results and was consistent with the measurement results (within their uncertainty ranges!), users could regard this as conflicting information. This is particularly important when it concerns the exceedence of a threshold.

Legally, a zone is either in compliance with a limit value or not. There may be significant uncertainties, but for legal reports on the situation of the preceding year a clear yes/no decision needs to be taken. The Guidance Working Group expressed the following view. If high quality measurements show exceedence, while models do not, the zone is taken to be non-compliant, in accordance with the usual procedure. The more difficult case is that no exceedences at measurement locations in the zone have been found, but exceedences were found by model calculations at other locations. The Guidance report recommends making a distinction between model use for compliance checking and other model use. If a model is used to assess whether areas in exceedence exist within a zone, where no exceedence has been measured, the model result is only regarded as a legal exceedence if the Member State is able to show that the calculations are sufficiently reliable to warrant the important consequences of a limit value being exceeded. Modelled exceedences that are not judged to be reliable enough to be taken as evidence, should trigger further investigation by measurement.

Accuracy

The directives specify the required accuracy not only for the measurement methods, as has also been done previously in the old air quality directives, but also for models used for the assessment – and this is new. Table 3 gives an overview of the accuracy requirements for models given in the first Daughter Directive.

Table 3. Overview of the accuracy requirements of the first Daughter Directive¹.

	Sulphur dioxide, nitrogen dioxide and oxides of nitrogen	Particulate matter and lead
Hourly averages	50% - 60%	-
Daily averages	50%	Not defined at present
Annual averages	30%	50%

¹⁾The accuracy for modelling and objective estimation is defined as the maximum deviation of the measured and calculated concentration levels, over the period considered by the limit value, without taking into account the timing of the events.

It is not easy to see how this should be translated to model that are being applied for compliance checking. In the first place, it is not clear what should be regarded as the model system; it would not be consistent to exclude the model input (emission data, meteorological data, background concentrations, etc), only the uncertainty in the model result counts for the air quality assessment. It is unclear what the requirements mean for the percentiles in which the limit values are expressed. Furthermore, it is unclear how this should be applied to a spatial pattern consisting of e.g. background levels and modelled local contributions and what the consequences of uncertainties in terms of limit values exceedences imply (see Section 3.1.3). These conceptual problems need to be addressed even before operational procedures for determining model uncertainties can be defined.

It is relevant to note that the provisions regarding assessment techniques that are given in the body of the daughter directives pertain to the assessment of the *existing* air quality, not regarding future air quality in the years when air quality limit values have to met (2005 or 2010, depending on the pollutant). Member States have to report every year on the air quality

in their territory in relation to the limit values and other air quality thresholds. The Daughter Directives specify the accuracy of the assessment methods.

Prognostic modelling is only implicitly mentioned in the air quality directives. When there are problem in complying with the limit values, plans or programmes need to be drawn up to ensure that the limit values will be attained in a specified time. Obviously, modelling is the most appropriate method to develop such plans and to justify that these plans and programmes are adequate, but the technique for this is not mentioned in the directives. So, it is left to the Member States how such modelling is done and it seems logical to conclude that the accuracy requirements given in the Daughter Directive do not apply to prognostic modelling.

URBIS

An example of an Air Quality Management System that has been developed to accommodate the requirements of the air quality directives is URBIS (URL 1). The purpose of this software system is to integrate the existing environmental data, models and standard calculation procedures in together with a Geographical Information System (GIS), matching the demands of information by city users on the one hand and availability of data as well as possible. URBIS has been designed to give integrated analyses for air pollution and other environmental aspects, in particular noise and external safety. Figure 2 gives an overview of the data and calculations needed to arrive at comprehensive maps of the air pollution in a city. Much emphasis was given to integrating a city-scale model with micro-scale (streets, small enterprises) models. To achieve the high spatial resolution required by the air quality directives, the system is based on a Gaussian plume model. For distances within about 30 m from roads, the microscale street pollution model CAR is used. The effect of buildings on nearby plume dispersion is taken into account by a simple method. Advantage could be taken of the fact that the limit values are defined as temporal statistical parameters, which results in less rigorous demands to the model performance than the calculation of a complete time series of hourly concentrations. An important step in the design of the model system was the development of an effective system of receptors, which would produce better results near roads and buildings than a rectangular set. The output of URBIS includes maps and tables presenting emissions, air pollution, noise and corresponding risks to policy makers, citizens and others.

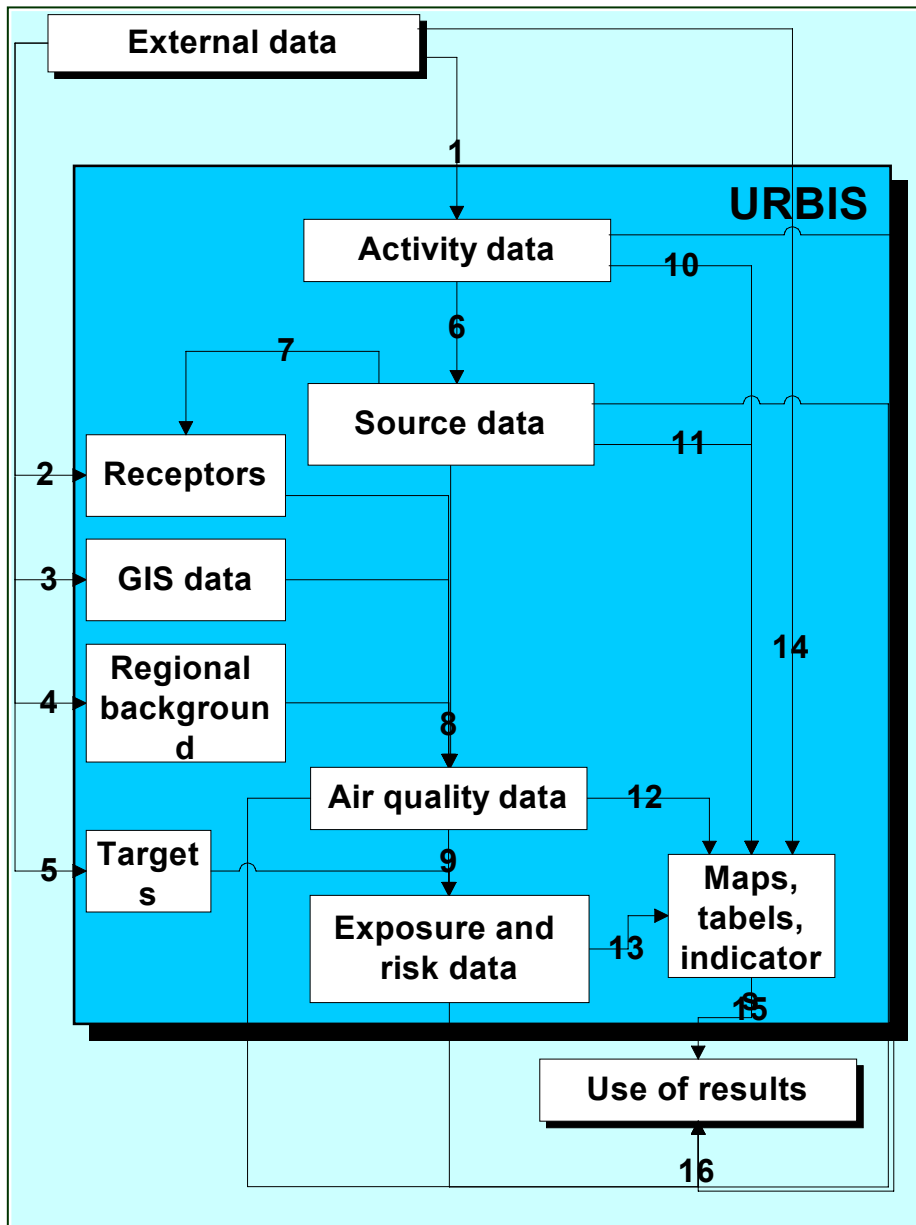


Figure 2. Overview of the structure of URBIS

Figure 2 gives an illustration of the high resolution of the output of URBIS, which is needed to determine whether limit values near roads or small enterprises are complied with or not.

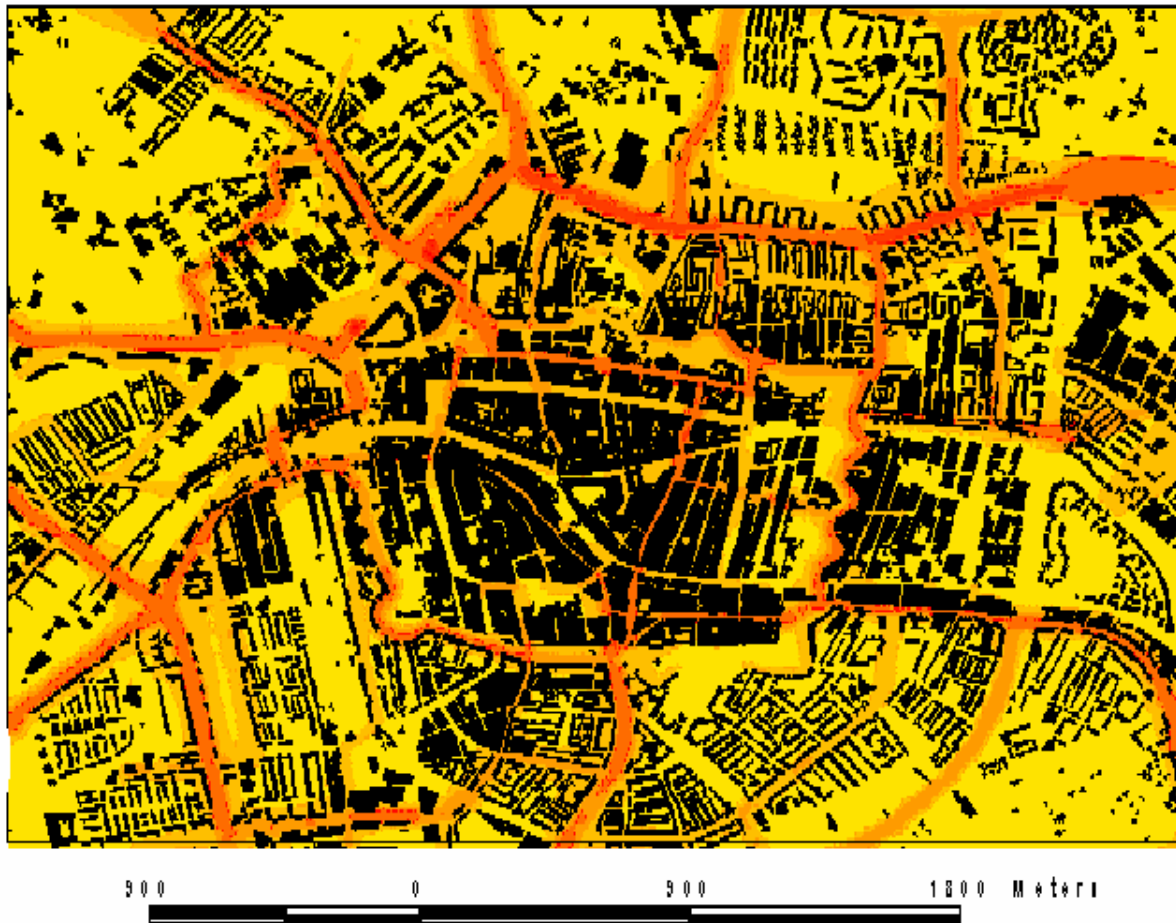


Figure 3. Example of the high-resolution output of URBIS: benzene annual mean concentrations in a city.

Conclusions

The more flexible approach of the new air quality directives towards the use of assessment techniques other than fixed monitoring stations has interesting implications for modellers.

In the first place, it is desirable that techniques become operational and available to combine measurement results and modelling results into an integrated territory-covering assessment of air pollution levels, such as data assimilation.

Secondly, models should be able to calculate the parameters in which the air quality thresholds are expressed. This means for many pollutants that the model should cover a full year, and for some pollutants that it should be able to calculate a high percentile of the time series of hourly or daily concentrations. Another important requirement is that the model should be able to provide the spatial resolution required: not only city background levels should be calculated, but also hot spots should be resolved sufficiently.

Thirdly, development on the conceptual level is also needed for using model results for legal assessment of air quality levels. The question of how to average the spatial patterns resulting from high-resolution model calculations has not been operationally answered yet. Also a more exact definition of the spatial properties of limit values is needed to legally interpret the maps produced by models. The accuracy specifications for models in the directives need conceptual elaboration before it can be related to the accuracy requirements e.g. a percentile.

Acknowledgement

This paper is largely based on the report of the Guidance Working Group (European Commission, 2002).

References

European Commission; Guidance on assessment under the EU air quality directives (2002), (<http://www.europa.eu.int/comm/environment/air/guidanceunderairquality.pdf>).

URL 1: http://www.health.tno.nl/en/about_tno/organisation/divisions/publichealth/urbis_en.html