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establishing guidelines for determination of contributions from the re-suspension of particulates following winter sanding or salting of roads under the Directive 2008/50/EC on ambient air quality and cleaner air for Europe

Abstract

Member States may under the EU Air Quality Directive 2008/50/EC indicate that for designated zones or agglomerations within which limit values for PM_{10} are exceeded in ambient air such exceedance is due to the re-suspension of particulates following winter sanding or salting of roads. This guidance recommends methods for the determination of the contributions of these processes to the ambient concentrations of PM.

These contributions have to be determined on a daily basis and can then be subtracted from each measured daily mean PM_{10} value. When also the annual mean limit value is exceeded, a reduced annual mean value can be calculated using the reduced daily mean values. The following methods are recommended:

Chemical analysis of chloride (for winter salting):

In most non-coastal areas of Europe, winter salting is the only source [Other anthropogenic – e.g. industrial – sources of salt have to be excluded.] of chloride in PM in the ambient air. Based on the chemical composition of the salt used, the total salt concentration can be determined by the chloride concentration in PM_{10}. This method requires daily chloride analysis of PM_{10} samples of the area of interest for all relevant days. In coastal areas, the contributions from winter salting and sea salt must be distinguished.

Coarse PM fraction (for winter sanding):

The contribution of winter sanding to PM_{10} concentrations can be approximated by a constant percentage of the coarse fraction (PM_{10}-$PM_{2.5}$), if the following criteria are fulfilled:

- Winter sanding activities have taken place and road-sand or remains of it have actually been present on the road.
- The road surface has been dry.
- The ratio $PM_{2.5}/PM_{10}$ is less or equal 0.5: This criterion excludes high contributions from long-range transport and selects days with a high fraction of coarse particles (both values from the same measurement station or region).

The numerical value of 50 % of the coarse fraction for the winter sanding contribution is an expert estimate for Finland and the best approximation available at present. According to experience currently available, this method works in Nordic and perhaps Baltic countries. In those countries, high concentrations of the coarse fraction during winter and spring give a clearly different picture compared to central Europe, where $PM_{2.5}/PM_{10}$ ratios are significantly higher and urban and road increments of the coarse fraction lower than in northern Europe[1]. Member States may apply different values, if these are documented by appropriate studies. The use of studded tyres in Nordic countries is quite common during winter. The quantification of emissions from road abrasion by studded tyres and by winter sanding is subject to broad research especially in Sweden and Finland. It is expected that these studies will ultimately yield a more robust estimate of the percentage of the coarse fraction that can be attributed to winter sanding activities.

[1] HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUS 2005, 2007, KUPIAINEN, K. 2007. Jari Viinanen, Markus Tarasti, personal communication.

Chemical analysis of mineral dust (for winter sanding):

At present, no preferred method based on the chemical analysis of mineral dust in PM_{10} samples is recommended. Such a method requires identifying the chemical properties of the sand used for traction control (silicate or carbonate) and chemical analysis of this mineral material in the PM_{10} samples. Contributions from other sources of mineral particles with similar chemical properties as the sand used for traction control (e.g. road abrasion, erosion of buildings, construction activities, deposition of dust eroded from any barren surface) have to be excluded.

Modelling is currently not recommended because further work, especially developing reliable emission factors and validation of modelling results, is needed first.

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1. INTRODUCTION

1.1. General

Concentrations of PM_{10} often exceed the limit values set in EU ambient air quality legislation. Winter sanding or salting may contribute to observed exceedances of the PM_{10} limit values. When it is possible to quantify this contribution, the EU Air Quality Directive 2008/50/EC[2] allows Member States to subtract this contribution from the total concentration for the purpose of demonstrating compliance.

1.2. Legal provisions

According to Article 21(1) of the Directive 2008/50/EC, 'Member States may designate zones or agglomerations within which limit values for PM_{10} are exceeded in ambient air due to the re-suspension of particulates following winter sanding or salting of roads'.

Article 21(3) requires: 'When informing the Commission in accordance with Article 27, Member States shall provide the necessary evidence to demonstrate that any exceedances are due to re-suspended particulates and that reasonable measures have been taken to lower the concentrations.'

Article 21(5) of this Directive states that guidelines for determination of contributions from the re-suspension of particulates following winter sanding or salting should be published by the Commission. These guidelines shall help to provide the evidence requested in Article 21(3).

Member States currently have to report air quality information annually in the questionnaire of Decision 2004/461/EC[3]; this includes data on the contribution of winter sanding or –salting[4] on exceedances of the PM_{10} limit value.

1.3. Aim and scope

This document aims at providing guidance on methods to identify and quantify the impact of winter sanding or salting, thus fulfilling the obligation of Article 21(5) of Directive 2008/50/EC. It documents the information or data which have been used to evaluate different methods and describes the following:

- an overview on how winter sanding or salting can influence PM_{10} concentrations levels and its spatial distribution;
- identification (and, if possible, quantification) of the impact of winter sanding or salting on PM_{10} concentrations levels and its spatial distribution, using examples from various European Member States;
- recommended methods to determine contributions of winter sanding or salting to PM_{10} exceedances, based on the experience from various countries;
- application and discussion of the suggested methods using exemplary datasets.

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2 OJ L 152, 11.6.2008, p.1

3 Commission Decision 2004/461/EC of 29 April 2004 laying down a questionnaire to be used for annual reporting on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC and under Directives 2000/69/EC and 2002/3/EC of the European Parliament and of the Council; OJ L 156, 30.4.2004, p.78

4 The questionnaire only referres to winter sanding, but in conformity with the extension to winter salting by Directive 2008/50/EC, winter salting can be included in the report.

1.4. Definitions

The impact of winter sanding or salting is analysed on a daily basis. Winter sanding or salting can influence the PM_{10} concentrations directly on a time scale of some hours or some days and has to be investigated at least on a daily basis. This is also the time scale for the more relevant PM_{10} daily limit value, which is more stringent than the annual average limit value.

The influence of winter sanding or salting on the annual mean concentration is very difficult to determine with sufficient accuracy without analysing individual days. However, since the impact of winter sanding or salting is related to shorter time periods only, the influence on daily averages is more relevant anyway. Compliance with the annual limit value may be checked by calculating the annual mean value from the daily mean values reduced by the contribution from winter sanding or –salting if the annual limit value has been exceeded.

Localization of the activity and short intervals in which it is applied importantly determine its spatial influence. This should be considered when the demonstration at a particular point is extrapolated to the assessment throughout the zone.

Winter sanding means dispersing mineral material for traction control with a grain size of usually some 100 µm or larger on the road surface or pavement. The smallest grain size, however, depends on the properties and preparation (sieving) of the sanding material.

Winter salting means dispersing salt (NaCl, $CaCl_2$, $MgCl_2$, CaMgAcetate, etc.) or a brine or solution of a salt for traction control on the road surface or pavement.

The impact of winter sanding on PM_{10} concentrations includes the increased abrasion of the road surface by the grinded sand ('sand paper effect') and subsequent suspension of the abrased material. Distinguishing direct suspension of traction control sand and abrasion of road surface material by the sand is in practice extremely difficult and not strictly necessary for the application of Article 21.

The article refers to '*…PM exceedances due to the re-suspension of particulates following winter sanding…*'. The re-suspension of dust from winter sanding occurs immediately after sand spreading, but in principle potentially also later in spring when snow and ice melt away and the streets dry out.

1.5. Origin of this guidance

This guidance is based on the results of a study conducted by the Umweltbundesamt of Austria for the European Commission (UMWELTBUNDESAMT, 2008**)**.

2. KEY PRINCIPLES

For the purpose of subtracting contributions to PM_{10} limit value exceedances attributable to winter sanding or salting it is necessary to provide a robust demonstration and quantification of the actual contribution from these sources to the concentrations, following the criteria given below.

Contributions must be attributed unequivocally to winter sanding or salting activities

It has to be demonstrated that the contribution of winter sanding or salting is indeed caused by this source. Contributions from other PM_{10} sources that might have a similar influence on (elevated) PM_{10} levels have to be excluded. Such sources may be:

- in case of a method based on chloride analysis: sea spray or salt from industrial sources;

- in case of a method based on the quantification of the coarse fraction (PM_{10}-$PM_{2.5}$): e.g. direct and indirect (re-suspension) emissions from road abrasion, especially caused by studded tyres (e.g. GUSTAFSON ET AL., 2008), tyre and break wear, construction activities, agriculture, natural sources, and re-suspension of material from such sources.

In northern European countries, where during winter studded tyres are quite common, the quantification of direct emissions from road abrasion by studded tyres and by winter sanding and the discrimination of these sources is being studied. No definitely approved method is available up to now; therefore, the method recommended in chapter 4.1 has to be considered preliminary.

Quantification must be sufficiently precise and accurate and appropriate to the averaging period of the limit value

The quantification of the winter sanding or salting must be as precise as possible. Every assessment comes with uncertainties, which Member States need to consider. The best estimate should be used at all times, and never high estimates. Uncertainties regarding the quantification must be provided when reporting.

The quantification of the contribution from winter sanding or salting has to be performed, as a first step, for candidate days exceeding the concentration of 50 µg/m³. Quantification for other days for which winter sanding might be deduced is relevant when the subtraction of winter sanding or salting is to be applied to the annual mean limit value; a 'reduced' annual mean value may be calculated from the 'reduced' daily mean values.

Representativeness of the measuring stations at which contribution is determined

Increased PM_{10} emissions by winter sanding or salting by large affect the PM_{10} concentration near the roads where sanding or salting are applied, and is as such usually measured at traffic related monitoring sites. The procedure to subtract the contribution of winter sanding or salting is to be applied for each measuring station separately. When the results are to be applied at wider spatial scale (assessment throughout the zone, development of air quality plans dealing with PM_{10}), a representative area of the affected monitoring site, restricted where appropriate to account for the specificity of the source and the different dispersion characteristics of the winter sanding/salting component, should be used.

The contribution of winter sanding or salting to the measured PM_{10} concentration has to be quantified in µg/m³ for each exceedance day under consideration

For each day for which a reduction due to winter sanding or salting is applied, this reduction has to be quantified as a concentration. It is not sufficient to 'remove' the daily PM_{10} value from the exceedance statistics after identifying an influence of winter sanding for this day.

The method to determine this contribution has to be documented

The method has to be documented as a reference to a report or a publication, which gives information about the input data used and the assumptions on which estimates are based.

3. IDENTIFICATION OF THE INFLUENCE OF WINTER SANDING OR SALTING ON PM_{10} LEVELS

3.1. Chemical composition

Winter sanding means to disperse mineral material – silicate or carbonate material – usually with a grain size of some 100 µm or larger on roads and pavements. This gravel is further ground by road traffic, and a fraction of the sanding gravel is broken down to a grain size around and below 10 µm. Increased wearing of road surfaces caused by sanding ('sand paper effect') adds to the total PM_{10} load. Some of this material is then suspended into the air by road traffic, wind or sweeping.

Winter sanding might therefore influence the chemical composition of PM_{10} by introducing a higher fraction of carbonate or silicate material compared to sites not influenced by winter sanding. However, often the traction control sand consists of the same mineral material as the road surface, which complicates the identification of the contribution from winter sanding (GUSTAFSON ET AL. 2008).

Winter sanding contributes to the mineral fraction of PM_{10}. Other sources of particles in this respect are the mechanical generation of particles from the earth surface (crustal material), long-range-transport (mainly desert dust or from large forest fires), road surface abrasion especially caused by studded tyres, or re-suspension from the road surface. An extraordinarily high fraction of mineral material – which might be further specified as silicate or carbonate – is therefore a well-suited indicator for winter sanding, especially if this high fraction occurs at traffic related sites only.

Winter salting usually means the dispersion of salt or a salt solution, which in most cases is NaCl, $CaCl_2$ or $MgCl_2$. This may be easily detected by chemical analysis. In regions affected by a significant impact of sea spray, this should be distinguished by assessing the meteorological transport conditions (wind speed and direction, backward trajectories). Also $NaNO_3$ may be used as a tracer for sea spray (since NaCl is converted $NaNO_3$ to during atmospheric transport).

3.2. Particle size distribution

The impact of winter sanding on PM_{10} is related to the release of rather large particles caused by mechanical grinding of even larger grains. PM_{10} contributions from winter sanding are therefore principally 'coarse' particles defined as the fraction (PM_{10}-$PM_{2.5}$). Since these particles are generated mechanically, it can be expected that their contribution to the $PM_{2.5}$ fraction is very low. The ratio of the coarse fraction to the total PM_{10}, or $PM_{2.5}/PM_{10}$, may therefore be a well-suited indicator for the impact of winter sanding, in comparison to sites known to be not influenced by winter sanding.

4. RECOMMENDED METHODS

A summary of the methods applied in different Member States is provided in Annex A, together with an analysis of how these methods work out in examples of other countries.

The examples from various Member States in Annex A showed the following:

- in northern European countries, at traffic related measuring sites the high ratio $PM_{2.5}/PM_{10}$ compared to urban and especially rural sites, is significantly affected by strong sources of coarse particles, a fraction of which can be attributed to winter sanding;

- suspension of salt originating from winter salting can be identified by chemical analysis of chloride, but other chloride sources, like sea spray, have to be excluded.

The Directive 2008/50/EC does not exclude dispersion modelling as a technique for determining the contribution of winter sanding and salting[5], but this method can at present not be recommended. Modelling (re)suspension of road dust is considered too uncertain to quantify the contribution from winter sanding (on a daily basis) at the present state of the art. Further information about the evaluation of models for PM emissions from (re)suspension as well as dispersion modelling for coarse PM is necessary to assess and recommend appropriate model approaches. Models may however be used to support determination of the spatial representativeness of the results of recommended methods as determined at specific sampling points. A distinction should however be made between dispersion modelling which depends on emission inventories, and source-receptor models. It should be noted that source-receptor models are able to successfully identify e.g. road salting, see WAHLIN P. ET AL. (2006), PERE-TREPAT E. ET AL. (2007).

At present, no standardised methods to assess the contribution by winter sanding based on chemical analysis of PM can be provided. The chemical composition of sanding material is diverse, and other sources with similar composition (e.g. road abrasion) might also contribute significantly to PMlevels. However, some principles for assessing these contributions are provided. Apart from the chemical analysis of salt compounds, no standardised, validated and commonly accepted method is available. The approach to deduct the impact of winter sanding applied in Finland is subject to further development however it is the only validated procedure available at present.

Therefore, the following methods are recommended.

4.1. Winter sanding - difference between $PM_{2.5}$ and PM_{10}

4.1.1. Conditions for using this method

The method attributes a fixed percentage of the coarse fraction PM_{10}-$PM_{2.5}$ to winter sanding. It has been developed in Finland and applies to conditions rather specific to northern European regions:

- long, continuous winter period during which traction control sand resides on the road without cleaning (due to permanent snow cover or temperatures below 0°C); road cleaning covers several weeks in spring;
- comparatively low – rural and urban – background concentrations (excluding exceptional transboundary events);
- high fraction of coarse particles (from winter sanding, as well as road abrasion).

PM_{10} and $PM_{2.5}$ are recommended to be measured with the same method to prevent any artefacts in the determination of the PM ratio.

Based on experience (including modelling) in Finland, 50 % of the coarse fraction (PM_{10}-$PM_{2.5}$) can be attributed to winter sanding; the other half of the coarse fraction is estimated to originate from road abrasion caused by studded tyres, tyre and break wear, and re-suspension of dust from other sources.

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5 The report under Article 21 would essentially include the description of the model inputs and application, and its results for days with identified impact, together with the information on the validation of the model including the explicit validation of the performance of winter sanding/ salting module in relation to model inputs.

The portion of 50 % of the coarse PM fraction attributed to winter sanding is considered to be a preliminary approximation, yet the best estimate available at present from validation work in Finland. Further research and investigation are needed in order to develop further the source apportionment methodology and to improve the accuracy of the quantification of the different sources contributing to PM concentrations. The use of the 50 % of the coarse PM fraction estimate should be thus considered with a 'provisional character' and could be updated as soon as the new findings will allow increasing its robustness.

4.1.2. Suggested procedure

The proposed method assumes the contribution from winter sanding to be 50 % of the coarse fraction (PM_{10}-$PM_{2.5}$) for each exceedance day with an identified impact from winter sanding. This contribution can be subtracted from the observed PM_{10} concentration if the following criteria apply:

1. Winter sanding activities have taken place, and there was road sand or the remains of it actually on the road or adjacent footpaths.

2. The road surface was dry.

3. The $PM_{2.5}/PM_{10}$ ratio is equal or less than 0.5. This criterion selects days with high local contributions of coarse particles and excludes high contributions from long-range transport (both values have to be from the same measurement station or within respective areas of representativeness).

4.1.2.1. Winter sanding activities

A prerequisite for considering winter sanding is that winter sanding activities have actually taken place – which restricts the considered period to the specific intervals in winter and spring season – and that gravel or sand on the road did actually originate from winter sanding.

Information about actual winter sanding activities and road sand or remains of it actually present on the road or pavements can be obtained from the municipal authorities responsible for winter sanding or from direct observation of the roads concerned.

4.1.2.2. Dry road surface

This information can be obtained from the municipal authorities responsible for winter sanding or from direct observation.

If this information is not available, meteorological information about precipitation and snow cover can be used. In this case 'dry road surface' conditions represent days without precipitation and with no snow cover. However, it is to be noted that in cold season moisture may condensate to road surfaces without precipitation. Best would be to monitor the road surface wetness but this kind of measurements are not usually available. Furthermore, snow cover does not necessarily correlate with road surface conditions, since winter maintenance aims to keep the main roads and streets free of snow cover at all times. In such cases expert judgment from local responsible bodies should be utilised.

4.1.2.3. Difference between the observed PM_{10} and $PM_{2.5}$ concentration

The impact of winter sanding to increased PM_{10} levels is assumed to be associated with a coarse fraction (PM_{10}-$PM_{2.5}$) of higher than or equal to 50 %.

This requires parallel monitoring of PM_{10} and $PM_{2.5}$:

- if possible, $PM_{2.5}$ measurements at the same site at which the PM_{10} exceedance has been observed;

- if these measurements are not available, $PM_{2.5}$ data at another comparable kerbside station in the same city can be used;

- if these measurements are not available, $PM_{2.5}$ data at an urban background station in the same city can be used (providing that the local contribution to $PM_{2.5}$ from road traffic is small compared to PM_{10} on days with a high impact of winter sanding);

- if these measurements are not available, PM_{10} data at an urban background station in the same city can be used.

If PM_{10} and $PM_{2.5}$ measurements are not taken at the same site, account should be taken of the respective representativeness of the measurements.

4.1.2.4. Contribution of long-range transport

The method is based on the assumption that increased PM_{10} concentrations are not caused by long-range transport both from natural or anthropogenic sources.

This criterion can be checked either by:

- rural background $PM_{2.5}$ measurements

- backward trajectories.

In northern Europe, the absence of long-range transport can normally be quantified by setting an upper threshold of 15 $\mu g/m^3$ for rural background $PM_{2.5}$ concentrations. However, long-range transport episodes of fine particles and road dust episodes (caused by winter sanding) occur often at the same time e.g. agricultural field-burning and wildfire smoke episodes from Russia occur often between mid-March and mid-May, see NIEMI ET AL. (2009). Daily mean $PM_{2.5}$ concentrations can be as high as 50 $\mu g/m^3$ due to long-range transport and coarse $PM_{10-2.5}$ concentration can be 100 $\mu g/m^3$ due to local road dust. In that case, road dust (coarse particles from winter sanding) would be the primary reason and long-range transport of $PM_{2.5}$ the secondary reason for the high PM_{10} value[6].

For exceptional transboundary events, it is appropriate to set an alternative criterion where the $PM_{2.5}$ contribution from long-range transport or local fine particles is less than half of the PM_{10} concentration: $PM_{2.5}/PM_{10} \leq 0.5$ (both values from the same measurement station or region).

If available, data from regional background stations can be used to assess the contribution from long-range transport.

In any region, backward trajectories can be used to assess the source regions of air masses. The absence of long-range transport reflects the following situations:

[6] While in the particular example the assessment may be used in the assessment of the application of Article 22(2) on time extension, it is not sufficient to identify that the daily PM_{10} exceedance on that day is 'due to re-suspension of particulates following winter sanding or salting of roads' as required under Article 21.

- long residence time (at least one day) in the vicinity of the end-point of the trajectories
- transport of air masses over regions with low emissions.

4.1.3. Example

The procedure applied in Finland (HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUS 2007, see Annex A, Section A2.1) is a well documented example of this method.

The method was found to give comparable results in Nordic Countries (see Annex A, Section A2.3) and Lithuania (Annex A, Section A2.2).

4.1.4. Critical discussion

The application of this method is limited to areas and to time periods where winter sanding is the dominant source of coarse particles (>2.5 µm).

The Finnish expert group (FEG) convened by the Ministry of the Environment proposed to attribute 50 % of the coarse fraction (PM_{10}-$PM_{2.5}$) to winter sanding during those days when direct and indirect effects of winter sanding could be expected and taking into account prevailing weather conditions. This is a rough estimate, taking into account other significant sources of coarse particles – direct and indirect (re-suspended) emissions from normal road wear and tear and road abrasion in particular caused by studded tyres, based on modelling in Finland and expert judgement. The fraction of 50 % may be questioned, and the quantity should be justified by further research.

If other percentages are applied, a documentation of the modelling or measurement based justification has to be provided.

4.2. Winter salting - chemical composition (chloride)

Exceedances due to the effect of winter salting may be shown for exceedance days using chemical analysis of 24-hour PM_{10} samples.

4.2.1. Conditions (requirements) to use this method

This method requires daily chemical analyses of the PM_{10} samples of those days for which a winter salting subtraction is intended to be applied. The analysis aims at detecting substances related to winter salting activities. In most cases this is a substance containing chloride. The corresponding information on the chemical properties of the salt dispersed on the road is necessary.

It has to be ensured that no other sources of salt have caused the increased PM_{10} concentration, notably sea spray. In regions with significant contributions by sea spray, the share of sea spray has to be quantified separately (see the Guidance on the quantification of the contribution of natural sources

4.2.2. Suggested procedure

The application of chemical analysis to identify the contribution of winter salting comprises:

- collecting the information about the chemical properties of the salt dispersed on the roads nearby the monitoring site;
- chemical analysis of chloride – or other relevant chemical constituents of the PM_{10} samples which correspond to the dispersed salt;

- ensuring that high concentrations of those constituents do not originate from other sources;
- subtracting the derived fraction of salting material from the PM_{10} concentration.

4.2.3. Example

This method has been applied on chemical composition data at several Austrian PM_{10} monitoring sites (Annex A, Section A2.4). The average contribution of chloride to winter PM_{10} concentrations covers a range from less than 1 % up to 5 %, representing NaCl contributions up to about 8 %. The highest chloride concentrations have been analysed at the Austrian site Klagenfurt Völkermarkterstraße, with a maximum of about 18 % during one winter episode.

The concentration of NaCl is calculated by the atomic weights of Cl (35.5 g/Mol) and Na (23.0 g/Mol). The NaCl content is subtracted from the total PM_{10} concentration. For the winter 2004/05, this procedure reduces the number of daily mean values >50 µg/m³ at Klagenfurt Völkermarkterstraße from 75 days to 66 days, at two other stations reductions from 82 to 76 days and from 53 to 52 days are found. The relative reduction in these cases roughly accounts for 15, 7 and 2 % respectively.

However, in the period with extremely high chloride concentrations (>15%), at Klagenfurt Völkermarkterstraße, PM_{10} was also very high, and only 4 of 11 exceedances (daily mean value >50 µg/m³) in this episode could be 'removed' by subtracting the NaCl content and could therefore be attributed to winter salting.

4.2.4. Critical discussion

The chemical analysis of chloride (or other components characteristic for the specific type of salt dispersed on the road) is assumed to be a well-suited method to quantify the impact of winter salting on PM_{10} concentrations.

The impact of sea spray can be subtracted as a contribution of a natural source according to Article 20 of the Directive 2008/50/EC. This contribution has to be considered separately from winter salting. When reporting reduced PM_{10} concentrations, it has to be ensured that the contributions from winter salting and sea spray are clearly distinguished, to avoid a certain salt content to be subtracted twice.

4.3. Winter sanding - Chemical composition (mineral dust))

No preferred method based on chemical analyses of mineral dust in PM_{10} samples can be recommended at the present state. At the time of developing this guidance, there were several investigations going on, dealing with chemical properties of road dust (see e.g. BAUER ET AL. 2007, JOHANNSEN 2008), but these are not focussing on suspension of sand used for traction control. There is no clear indication from the available analysis data that winter sanding influences – i.e. increases – the silicate or carbonate concentrations. Other potential major sources of mineral material are to be considered like abrasion of crustal material, road abrasion, re-suspension of dust from other sources such as construction and industrial activities. Quantification of emissions of mineral material and attribution of PM_{10} fractions to specific sources is very difficult.

The requirements for a method to determine the contribution of winter sanding to PM_{10} concentrations by chemical analyses of mineral dust can be outlined as follows:

- identification of the chemical properties of sand used for traction control (at least differentiating between silicate and carbonate);

- chemical analysis of PM_{10} (e.g. using X-ray fluorescence analysis);
- exclusion of other sources of mineral particles of the same chemical properties as the sand used for traction control, such as road abrasion (especially caused by studded tyres), erosion of buildings, construction activities, deposition of dust eroded from any barren surfaces.

Additional prerequisites for the suspension and re-suspension of sand used for traction control are:

- presence of sand – both on roads and sidewalk – originating from sanding activities (must be documented);
- dry road surface.

4.4. Review of experience gained by Member States

It is recommended to evaluate and review the experience gained with the different approaches in regular intervals. Based on the outcome of these reviews, this guidance should be adapted as appropriate.

5. REPORTING

In order to apply the provisions under Article. 21 of Directive 2008/50/EC, the determination of contribution of winter sanding or salting has to be documented. The document should be made available to the Commission and to the public (online or in the Central Data Repository), updated annually to demonstrate the contributions to individual exceedances in the reporting year. There are no specific requirements for the structure of the document, but it has to include explicit reference to the aim (application of Article 21), the role/participation of competent authorities or bodes designated under Article 3 of Directive 2008/50/EC for the assessment of ambient air quality and analysis of assessment methods, the temporal and spatial scope (air quality zones and individual exceedances), the description of methodology and results: identification and quantification information. The application of all key principles set out in Chapter 2 has to be identifiable in the document.

Information about exceedances of limit values due to natural contribution are currently reported as part of the questionnaire set up by Decision 2004/461/EC.

On the level of zones, Form 8c compares the original total PM_{10} assessment results with the limit values and any applicable margin of tolerance. The deduction of contributions from winter sanding or salting may bring some zones in compliance but this is identified in Form 24 and is not to be reported under Form 8c.

Individual cases of exceedance are presented in Form 11h and Form 11i.

In Form 24a of the questionnaire, the total as well as the reduced number of exceedances of the daily limit value of 50 $\mu g/m^3$ is to be given. Annual means, exceeding the long-term limit value as well as those results reduced by contributions from winter sanding or salting are to be reported in Form 24b. When deduction is to be applied to assessment results provided as spatial information (concentration grid, area of exceedance), a representative value such as highest assessed concentration in the area should be provided, associated with a short description of the information.

In all cases, an electronic link to the report(s) is to be provided at the rightmost column in Form 24.

Both information items – the essential information on contribution and the link to the external report are to be provided in the annual air quality report, if necessary by a subsequent resubmission. Otherwise the Member States' application of the provision under Article 21 will not be considered for the purpose of the assessment of compliance by the Commission.

An example of a possible report on quantification of winter sanding contribution to exceedances is provided in Annex B.

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ANNEX

ANNEX A EXISTING PROCEDURES TO ASSESS THE IMPACT OF WINTER SANDING OR SALTING

Increased PM_{10} concentrations due to 'winter related road traffic emissions' are recognised as a problem in several northern regions, both in Europe and North America. Such emissions comprise road abrasion by studded tyres, grinding and subsequent suspension/re-suspension of traction control sand, suspension of traction control sand, and increased road abrasion (and subsequent suspension of the abrased particles) due to the traction control sand ('sand paper effect').

The most thorough research on winter sanding related PM_{10} problems seems to have been conducted in Finland (see especially KUPIAINEN 2007). In Sweden and Norway road abrasion by studded tyres is considered as the major issue (see e.g. JOHANNSEN 2008, OMSTEDT 2005).

Also some studies in (western) North America address the problem of PM re-suspension due to winter sanding (BRITISH COLUMBIA 2005, GERTLER 2006, KUHNS 2003), but they relate to climatic situations that are somewhat different from those in Europe (high precipitation in British Columbia, dry climate in the Lake Tahoe basin). The studies include laboratory simulations for road abrasion and suspension, in-situ measurements on roads, as well as modelling.

In addition to studying the information above, Austrian data on the chemical speciation of PM_{10} have been analysed in more depth for the purpose of this guidance.

A1 Subtraction of winter sanding or salting in 2006

The methods recommended in this report for the quantification of the impact from winter sanding or salting on (elevated) PM_{10} levels have been derived from procedures currently applied in various Member States. Information was retrieved as a first step from the information submitted by Member Satest for the year 2006.

According to the overview of the reports by Member States on their ambient air quality under Commission Decision 2004/461/EC, prepared by ETC/ACC for the year 2006 (ETC/ACC 2007), subtraction of winter sanding was applied in the five Member States Estonia, Finland, Lithuania, Latvia and Slovakia.

Table 1: Influence of the subtraction of winter sanding on the number of stations exceeding the limit values for PM_{10} in 2006. The table relates only to stations to which the reduction has been applied (source: ETC/ACC 2007)

	Daily limit value		**Annual limit value**	
MS	**Before reduction**	**After reduction**	**Before reduction**	**After reduction**
EE	1	*)		
FI	2	0		
LT	3	0		
LV	2	2	2	2
SK	24	21	8	7

*) *Number of exceedances after reduction not reported*

In the annual air quality report, a reduction was applied for two stations in Helsinki. For the station Helsinki Mannerheimintie the number of exceedances of the critical daily mean concentration (50 µg/m^3) was reduced from 37 to 13, for Helsinki Töölöntulli from 59 to 26. Hence compliance was found for both stations after applying the reduction.

In Lithuania the reduction was applied to 12 stations, three of which showed exceedances before the reduction and none afterwards. Therefore, in Lithuania compliance was also found by the reduction.

For the development of this guidance, the responsible authorities of all five Member States were contacted to obtain more information about the reduction procedure.

A2 Methods based on the assessment of the coarse fraction (PM_{10}-$PM_{2.5}$)

A2.1 Procedure for reduction applied in Finland

For 2005 a reduction for exceedances of the daily mean PM_{10} concentration of 50 µ/m^3 due to winter sanding was applied to two Finnish monitoring sites. The procedure is described in a report about PM_{10} exceedances due to winter sanding (HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUS 2007). Each exceedance day is checked for the cause of the elevated PM_{10} levels. A PM_{10} exceedance is assumed to be caused mainly by winter sanding if the following conditions apply:

- dry weather conditions
- rather low $PM_{2.5}$-levels at the same site (or at a background site)
- no indications for long-range transport
- high PM_{10}-levels at several sites.

In this procedure, the daily mean values for which an influence of winter sanding was identified were totally removed from the statistics (and not reduced by the winter sanding contribution and then used for the exceedance statistics).

Figure 1 shows PM_{10} and $PM_{2.5}$ levels at the monitoring site Helsinki Mannerheimintie for the year 2005. Highest PM_{10} levels occurred during April and May. During this time period the $PM_{2.5}$ levels were much lower. Overall, the share of $PM_{2.5}$ in PM_{10} was only 35% (2006). For the days when the exceedance was attributed to winter sanding, the $PM_{2.5}$ share accounts for only 18% of PM_{10}. This indicated a very high amount of mineral particles. By contrast, the $PM_{2.5}/PM_{10}$ ratio in Central Europe varied between 60 and 80%. Hence, for attributing an exceedance to winter sanding more sophisticated methods might be needed in central European countries.

The impact of winter sanding on the PM_{10} concentration (and the $PM_{2.5}/PM_{10}$ ratio) is highest in spring, when the snow cover on the roads has disappeared and the roads begin to dry up; the same seems to be the case in Lithuania (see Section A2.2). During winter, streets are continuously covered by snow, and sanding material is not (re-)suspended.

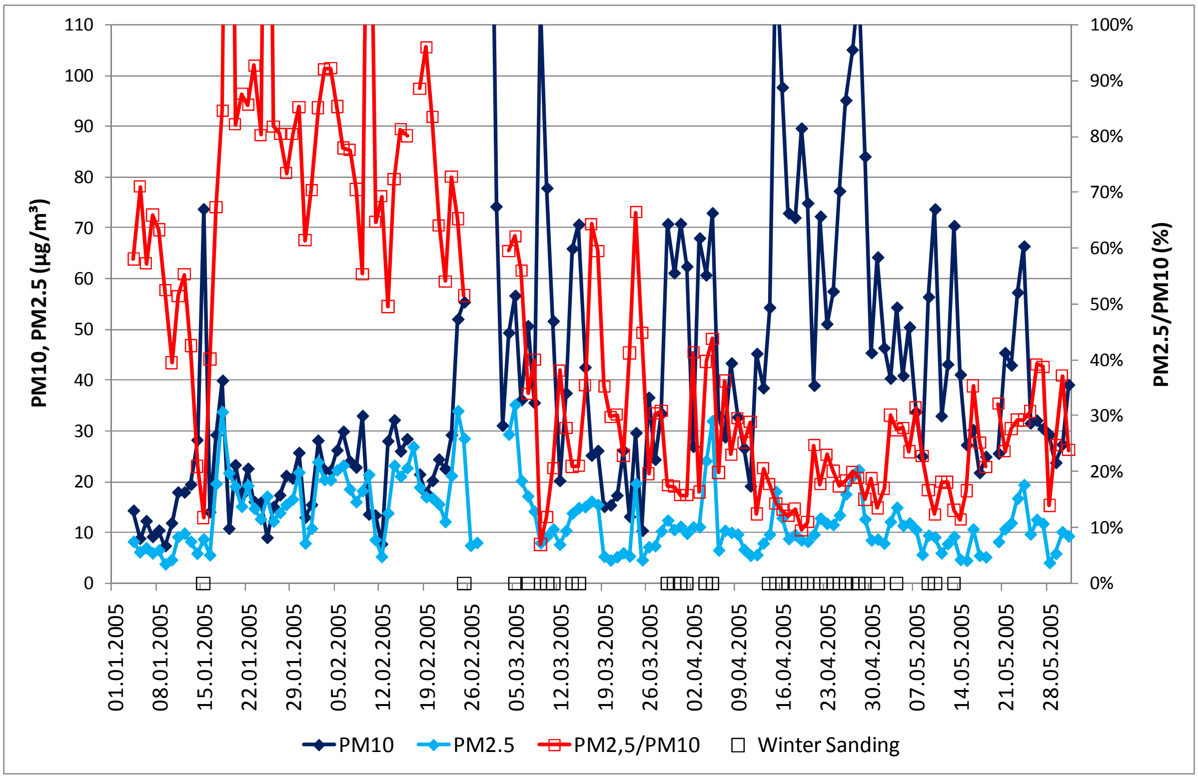

Figure 1: PM_{10}, $PM_{2.5}$ and $PM_{2.5}/PM_{10}$ levels (as %) at the monitoring site Helsinki Mannerheimintie in the year 2005 (source: AIRBASE[7], HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUS 2007)

In the Finnish report measures to reduce the contribution from winter sanding are also described. These include:

- the use of sand that has been washed and sieved (to extract 'fine' particles);
- reducing the use of sand and increasing the use of salt;
- intensifying street cleaning.

Following further discussions[8], experts from Finland (FEG, Finnish expert group) in recent years improved the methodology, specifying criteria for the assessment of the impact of winter sanding on PM_{10} levels in more detail:

- *'Dry weather conditions'* – alternatively: dry road conditions.
- '*$PM_{2.5}$ levels at the same site (or at a background site) are rather low*': the coarse fraction PM_{10}-$PM_{2.5}$ is higher than approximately 25 µg/m³.
- *'Long-range transport is not the major source of PM_{10}'*: the contribution of $PM_{2.5}$ is less than half of the PM_{10} concentration.

7 http://www.eea.europa.eu/themes/air/airbase
8 Personal communication with T. Lahtinen, Ministry of Environment.

- The time period considered covers the winter season from beginning of November to end of May.
- Additional sources of coarse particles in winter are enhanced road abrasion especially caused by studded tyres and by the ground sand ('sand paper effect'). Separation of these contributions is not easy.
- About 50 % of the coarse fraction PM_{10}-$PM_{2.5}$ is attributable to winter sanding.
- If $PM_{2.5}$ is not measured at the same site, the following information – with decreasing suitability – may be used:
  - $PM_{2.5}$ data from another, similar (traffic related) site.
  - If no representative $PM_{2.5}$data are available, PM_{10} background concentrations can be used.

An evaluation of this method is given in Section A2.3.

It has to be noted that the attribution of 50 % of the coarse fraction to winter sanding (including the 'sand paper effect') is an estimate developed by Finnish experts; the other half of the coarse fraction is assumed to come from road abrasion by studded tyres, break and tyre abrasion and re-suspension of road dust from other sources. This estimate is based on long experience about the situation in Nordic countries, with air quality problems related to non-exhaust particle emissions, as well as modelling approaches and estimates on emissions; for ongoing research see e.g. KUPIAINEN 2007. Further investigation to quantify the percentage of coarse particles originating from winter sanding will provide more precise estimates.

A2.2 Procedure for reduction applied in Lithuania

Similar to Finland, the $PM_{2.5}/PM_{10}$ ratio is used as an indicator for the impact of winter sanding on PM_{10} levels at urban kerb side locations in Lithuania. The period affected by low $PM_{2.5}/PM_{10}$ ratios usually is March to May. A short documentation and the graphs shown in Figure 2 have been provided in PERKAUSKAS (2008). However, no detailed procedure for identifying PM_{10} values affected by winter sanding was given. In absence of sufficient data and information no further assessment of the method proposed can be provided so far.

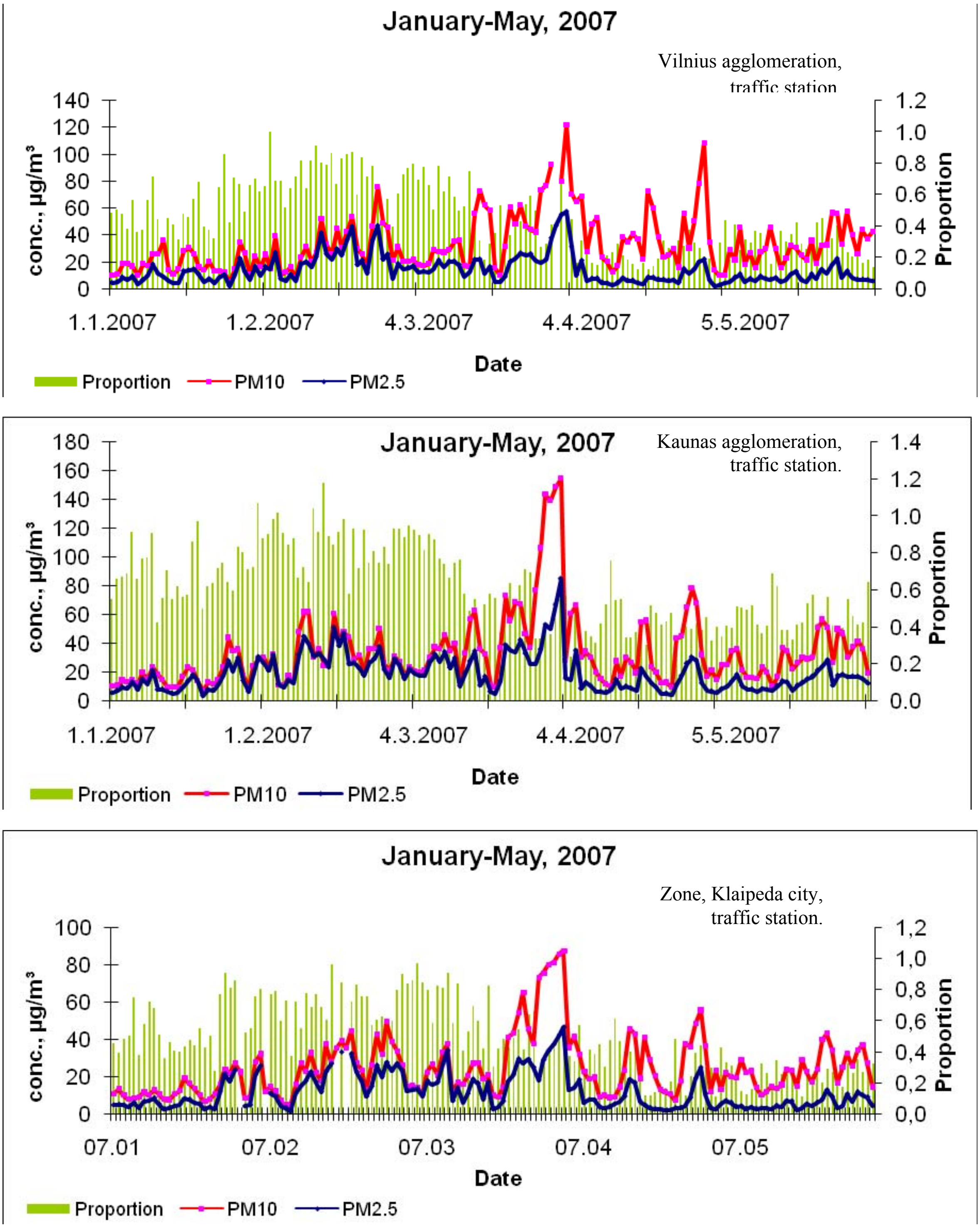

Figure 2: Concentrations of PM_{10} and $PM_{2.5}$, $PM_{2.5}/PM_{10}$ ratios at kerb side locations in large cities in Lithuania, 2007 (source: Perkauskas, 2008)

A2.3 Further investigation of European PM data

A2.3.1 Scandinavia

The method developed and applied in Finland was tested with other datasets from northern Europe and Austria.

In all Scandinavian countries, very low $PM_{2.5}/PM_{10}$ ratios occur over long periods in winter, which can be attributed to significant sources of coarse particles (winter sanding, road abrasion by studded tyres and sand). However, only Finland up to now applies the above mentioned method (Section A2.1) to quantify the effect of winter sanding; in Norway and Sweden, the focus is set on the effect of studded tyres.

In this section, a modification of the original method developed and used in Finland, further on referred to as 'modified FEG method', is applied on PM_{10} data sets in Scandinavian cities where the limit value (for the daily mean) was exceeded in recent years, and where $PM_{2.5}$ data are available.

The criteria are:

- time period: January to May and November to December
- difference (PM_{10}-$PM_{2.5}$) higher than 25µg/m³
- $PM_{2.5}$ at rural background is lower than 15µg/m³.

If these conditions are fulfilled, the PM_{10} value is reduced by 50 % of the coarse fraction (PM_{10}-$PM_{2.5}$) [9].

These criteria differ from those used in 2006 in HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUS (2005, 2007). They also differ from the final and streamlined ones that, after further discussion with FEG experts, are proposed in this guidance. However, since in all cases (at days with PM_{10} mean values above 50 µg/m³) which fulfil the criterion 'PM_{10} - $PM_{2.5}$ higher than 25 µg/m³' the $PM_{2.5}$ regional background was well below 15 µg/m³, it is likely that they give the same results.

No information about 'dry' weather or road conditions is available; therefore the test 'ignores' this criterion. It should be noted that these criteria partly differ from those applied in the Finnish annual reports.

The measuring stations listed in Table 2 are tested. The selection is based on:

- the availability of PM_{10} and $PM_{2.5}$ measurement data at the same kerb-side station or at least at kerb-side stations in the same city in Airbase;
- exceedance of the PM_{10} short term limit value (more than 35 days per calendar year with a daily mean concentration >50 µg/m^3).

Table 2: Monitoring sites used for testing of Finnish method

Country	**Measuring station in exceedance (name, EoI code)**	**$PM_{2.5}$ urban**	**$PM_{2.5}$ rural background**	**Year**
FI[10]	Helsinki Runeberginkatu (FI0142A)	Helsinki Runeberginkatu	Virolahti[11]	2003

[9] in HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUS 2005, 2007, the days affected by winter sanding are completely removed.

Country	Measuring station in exceedance (name, EoI code)	$PM_{2.5}$ urban	$PM_{2.5}$ rural background	Year
FI	Helsinki Mannerheimtie (FI0148A)	Helsinki Mannerheimtie	Virolahti	2005, 2006
NO	Trondheim Elgeseter NO0060A)	Trondheim Bakke Kirke[12]	Birkenes	2005
NO	Trondheim Elgeseter (NO0060A)	Trondheim Elgeseter	Trondheim Teknostollen	2006
NO	Lillehammer Bankplassen (NO0074A)	Lillehammer Bankplassen	Birkenes	2005
NO	Lillehammer Bankplassen (NO0074A)	Lillehammer Bankplassen	Lillehammer Barnehagen	2006
DK	København H.C.Andersens B. (DK0034A)	København H.C.Andersens B.	Lille Valby[11]	2004, 2005
DK	København H.C.Andersens B. (DK0034A)	København H.C.Andersens B.	Lille Valby	2006
DK	København 1257 (DK0030A)	København 1257	Lille Valby[11]	2005

Table 3 compares the number of daily mean values above 50 µg/m³ calculated by different methods:

- original measurement data;
- annual reports: based on information published in HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUS 2005, 2007;
- FEG method.

Table 3: Comparison of the calculated impact of winter sanding on the exceedance of 50 µg/m³ PM_{10} as daily mean value at different measuring stations

Monitoring site (name, EoI code)	Year	Number of days/a > 50µg/m³		
		Original data	Annual report	Modified FEG method
Helsinki Runeberginkatu (FI0142A)	2003	43	28	26

10 In Finland, only at Helsinki Runeberginkatu (2003) and Mannerheimtie (2005, 2006) the PM_{10} limit value (more than 35 daily means above 50 µg/m³) was exceeded.

11 PM_{10} used in absence of $PM_{2.5}$

12 Insufficient data coverage of $PM_{2.5}$ at Trondheim Elgeseter 2004.

Monitoring site (name, EoI code)	Year	Number of days/a > 50µg/m^3		
		Original data	**Annual report**	**Modified FEG method**
Helsinki Mannerheimtie (FI0148A)	2005	50	22	19
Helsinki Mannerheimtie (FI0148A)	2006	36		22
Trondheim Elgeseter (NO0060A)	2005	42		21 (18)[13]
Trondheim Elgeseter (NO0060A)	2006	87		62 (55)
Lillehammer Bankplassen (NO0074A)	2005	44		24 (23)
Lillehammer Bankplassen (NO0074A)	2006	37		19 (16)
København H.C.Andersens B. (DK0034A)	2004	84		65
København H.C.Andersens B. (DK0034A)	2005	87		82 (76)
København H.C.Andersens B. (DK0034A)	2006	94		93
København 1257 (DK0030A)	2005	39		39

The differences between the data given in the Finnish annual reports Helsinki for 2003 and 2005 on the one hand and those calculated by the procedure proposed by FEG originate from slightly different criteria; the annual reports do not attribute exceedances in November and December to winter sanding, which slightly reduces the number of days exceeding 50 µg/m^3.

The modified FEG method reduces the number of exceedance days at Helsinki Runeberginkatu by 40 %, in Helsinki Mannerheimintie between 40 and 60 %.

The modified FEG method could also be applied on PM measuring stations in Stockholm, which show, similarly to Finland, quite high proportions of coarse particles during winter. However, in Stockholm the coarse fraction originates solely from road abrasion by studded tyres and re-suspension of road dust, and no winter sanding occurs there. Nevertheless, the application of the modified FEG criteria reduces the numbers of exceedance days on average by one third at the station Stockholm Hornsgatan and about one half at Stockholm Norrmalm and Sveavägn.

This demonstrates the uncertainties in distinguishing re-suspension of traction control sand and road abrasion by studded tyres and the necessity for further research on the sources of coarse particles and the need for application of further analysis where such additional processes can be identified.

13 Including days with winter sanding in October

As already stated in Section A2.1, the percentage of 50 % proposed by FEG is a preliminary expert estimation, but the best available at present. It will be further refined by future research.

The number of exceedance days reduced by applying the 'modified FEG criteria' shows a fairly linear dependence on the fraction of the coarse particles 50 % which is attributed to winter sanding. A variation of 10 % of this fraction alters the number of exceedance days by about 10 %.

The modified FEG method reduces the number of days exceeding 50 µg/m³ at most monitoring sites in Finland and Norway by 40 to 60 %. As a consequence, the number of exceedances of the critical daily mean value of 50 µg/m³ is reduced to or below 35 at all sites in Helsinki and several sites in most years in Norway. The reduction of days exceeding 50 µg/m³ is much lower in København. One reason for the difference is the comparably high background $PM_{2.5}$ concentration (above 15 µg/m³ as annual mean).

A2.3.2 Austria

In order to test the applicability of the modified FEG method to regions in Europe with totally different climatic conditions, PM data from Austria were investigated. The availability of different types of data and information from Austria facilitated the evaluation of these data for the possible identification of an impact of winter sanding or salting. Beside the PM_{10} values data on the chemical composition and the size distribution were used.

Table 4 lists those measuring stations and periods where data either on the chemical composition (see Section A2.4) or the $PM_{2.5}/PM_{10}$ ratio are available. Most data on the chemical composition have been taken from a project entitled 'AQUELLA' (BAUER ET AL. (2005), BAUER ET AL. (2006), BAUER, H. ET AL. (2007); JANKOWSKI, N. ET AL. (2007); PUXBAUM, H. (2004)); in this project, chemical analysis were averaged over several days.

Table 4: Overview of Austrian $PM_{2.5}$ data and chemical speciation data

Zone	Monitoring site (name, EoI code)	PM_{10} LV exceeded	$PM_{2.5}$	Chemical Analysis
AT_02	Klagenfurt Völkermarkterstr. (AT0170A)	2005 – 2007	March 2005 – Dec. 2007	21.10.2004 – 31.3.2005[14]
AT_40	Linz ORF-Zentrum (AT0032A)	2002 – 2006	Oct. 2000 – Sept. 2001	Oct. 2000 – Sept. 2001[15]
AT_40	Linz Neue Welt (AT0039A)	2001 – 2003, 2005, 2006	Dec. 2004 - Dec. 2007	April 2005 – Jan. 2006[16]
AT_40	Linz Römerberg (AT0183A)	2005 – 2007		April 2005 – Jan. 2006[14]
AT_05	Salzburg Rudolfsplatz (AT0038A)	2003, 2005, 2006	Feb. 2005 – Dec. 2007	Jan. – Dec. 2004[17]

[14] Not yet published
[15] AUPHEP (2004)
[16] JANKOWSKI ET AL. (2007)
[17] Not yet published

Zone	Monitoring site (name, EoI code)	PM_{10} LV exceeded	$PM_{2.5}$	Chemical Analysis
AT_60	Graz Don Bosco (AT0205A)	2001 – 2007		Jan. – Dec. 2004[18]
AT_07	Innsbruck Zentrum (AT0099A)	2005, 2006	Jan. 2005 – Dec. 2007	
AT_09	Wien Rinnböckstr. (AT0088A)	2003 – 2007		Jan. – Dec. 2004[19]
AT_09	Wien Spittelauer Lände ((every 6th day)	1999, 2000 (extrapolated)	Oct. 1999 – Nov. 2000	Oct. 1999 – Nov. 2000[20]
AT_09	Wien Taborstraße (AT0021A)	2005 – 2007	Jan. – Dec. 2007	
AT_09	Wien Währinger Gürtel (AT0082A)	2005, 2006	June 1999 – May 2000 Jan. 2005 – Dec. 2007	June 1999 – May 2000[16]
AT_09	Wien Erdberg		May 2001 – May 2002	

In comparison to northern Europe, the $PM_{2.5}/PM_{10}$ ratios are quite high, and the difference between PM_{10} and $PM_{2.5}$ – in absolute concentrations – is low.

The application of the modified FEG method yields no major 'impact' of winter sanding on PM_{10} exceedances. As Table 5 shows, the number of exceedances is being reduced by only a minor amount.

Table 5: Test of the FEG-method presented in Section A2.1 on Austrian data

Monitoring site (name, EoI code)	Period	Original data	Reduced
Klagenfurt Völkermarkterstraße (AT0170A)	March – Dec. 2005	44	40
Klagenfurt Völkermarkterstraße (AT0170A)	2006	79	76
Klagenfurt Völkermarkterstraße (AT0170A)	2007	42	42
Linz Neue Welt (AT0039A)	2005	48	43
Linz Neue Welt (AT0039A)	2006	57	46
Linz Neue Welt (AT0039A)	2007	35	34
Salzburg Rudolfsplatz (AT0038A)	2005	39	29

18 BAUER ET AL. (2005), BAUER ET AL. (2007)
19 PUXBAUM, H. (2004), BAUER ET AL. (2006)
20 UMWELTBUNDESAMT (2002)

Salzburg Rudolfsplatz (AT0038A)	2006	56	55
Wien Taborstraße (AT0038A)	2007	45	41

Long-range transport has been identified by backward trajectories, considering both, anthropogenic sources and Sahara dust. The criterion used in Finland for long-range transport is not applicable in Austria, since situations with long-range transport are usually associated with high rural background $PM_{2.5}$ concentrations. Averaged over days with PM_{10} concentrations above 50 µg/m³ in Vienna during the winter season, the $PM_{2.5}$ concentration at the EMEP site Illmitz is 43 µg/m³ (however, it is even higher – 52 µg/m³ – averaged over PM_{10} exceedance days classified as 'regional accumulation').

Figure 3 gives, as an example, the daily mean values of $PM_{2.5}$ and $PM_{2.5}$-PM_{10} at Wien Taborstraße (central urban, kerb side). The average $PM_{2.5}$/PM_{10} fraction is 70 %.

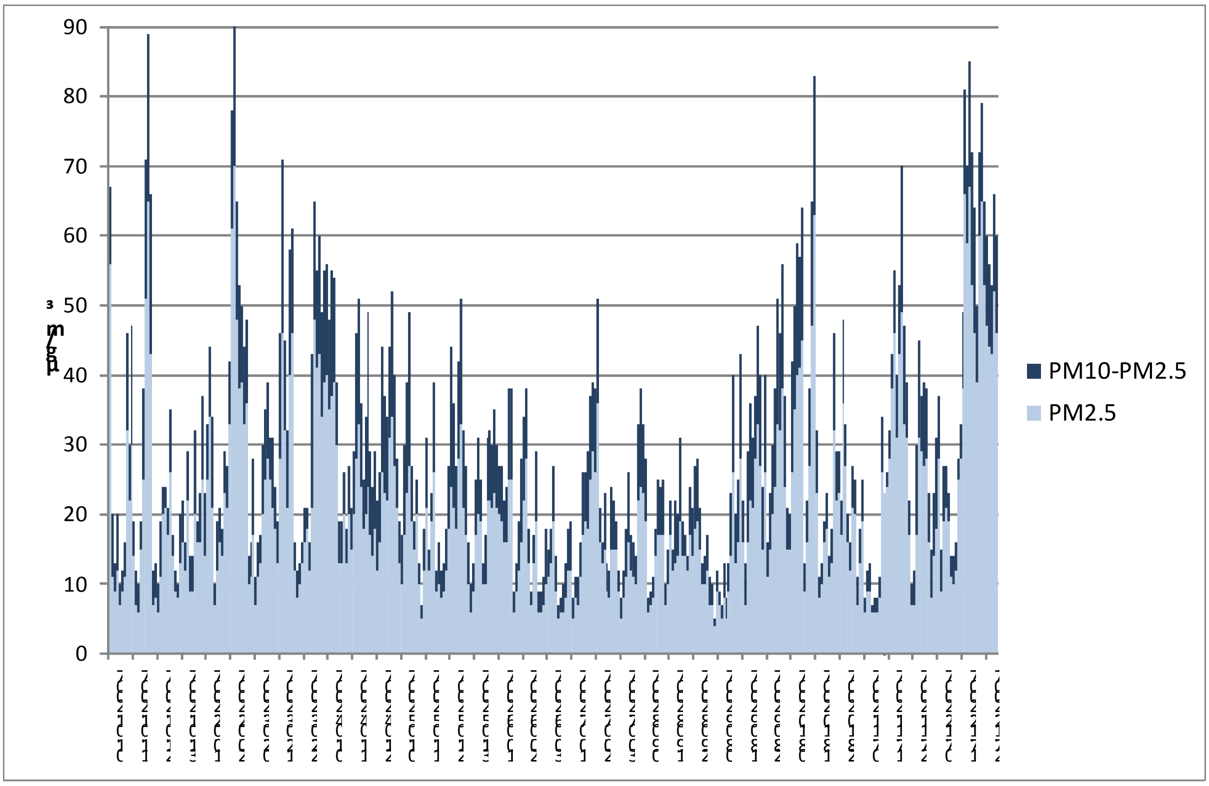

Figure 3: ($PM_{2.5}$ and PM_{10}) concentrations at Vienna, Taborstraße (central urban, kerb side), daily mean values 2007

To conclude, in central European countries such as Austria, the relation of $PM_{2.5}$ to PM_{10} does not exhibit a clear pattern related to winter sanding (or salting). Significant differences compared to northern Europe concern:

- higher rural background $PM_{2.5}$ concentrations
- lower urban increments both for PM_{10} and $PM_{2.5}$
- lower coarse fractions even at kerb-side locations.

Statistics of the $PM_{2.5}/PM_{10}$ ratio do not suggest a major impact of winter sanding on PM_{10} exceedances. Averaged over all winter months, the $PM_{2.5}/PM_{10}$ ratio in Klagenfurt Völkermarkterstraße is 0,7 both for days with PM_{10} concentrations below and above 50 µg/m³; in Vienna Taborstraße, it is 0,72 for days below and 0,76 for days above 50 µg/m³.

A2.3.3 Discussion of emissions of coarse particles in northern Europe

In northern European countries, the specific climatic situation leads to very high emissions of coarse particles from traffic related sources:

- road abrasion by studded tyres
- re-suspension of traction control sand
- increased road abrasion by traction control sand.

In Nordic countries during winter, studded tyres are quite common, and the quantification of emissions from road abrasion by studded tyres and by winter sanding and the discrimination of these sources is subject to broad research especially in Sweden and Finland (GUSTAFSON ET AL., 2008, KUPIAINEN ET AL. 2002, 2007, TERVAHATTU ET AL., 2006).

Sand may increase the emission level by 10 times or more immediately after sanding. This happens only when road surfaces are dry, but the dust formation processes (by road surface abrasion and grinding of traction control sand) are in effect also in wet and icy conditions when the dust is not released to the air. Re-suspension of dust which has been formed during sanding occasions earlier in winter (e.g. during wet/snowy/icy conditions) and which has accumulated in the street environment causes an indirect emission pathway. The previously formed dust is released back to street environment in spring (and sometimes already during warm and rainless winter days) when ice and snow melt and surfaces dry out. After the release, especially the PM_{10} sized dust moves rapidly in the street environment due to traffic flow patterns (see for example PATRA ET AL. 2008) and becomes re-suspended.

A3 Chemical composition - Austrian data

Data on chemical composition of PM_{10} from Austrian monitoring sites – listed in Table 6 – were analysed with respect to a possible influence of winter salting.

No other data for appropriate analysis or information about winter sanding or salting activities were available. Indicators for winter sanding or salting are the fractions of mineral material and chloride in PM_{10}. The only source of chloride in Austria is winter salting, since sea spray is of no relevance. Mineral material, however, may originate from various sources. Besides winter sanding, the re-suspension of any dust by road traffic as well as road abrasion, industrial (mainly fugitive) sources, erosion of crustal material or desert dust (through long-range transport) may cause elevated mineral dust concentrations.

Figure 4 gives, as an example, the chemical composition (annual mean) at two monitoring sites in Graz (Graz Don Bosco: kerb side, Graz Süd: residential, commercial) and Klagenfurt (Völkermarkterstraße: kerb side; Koschatstraße: urban background).

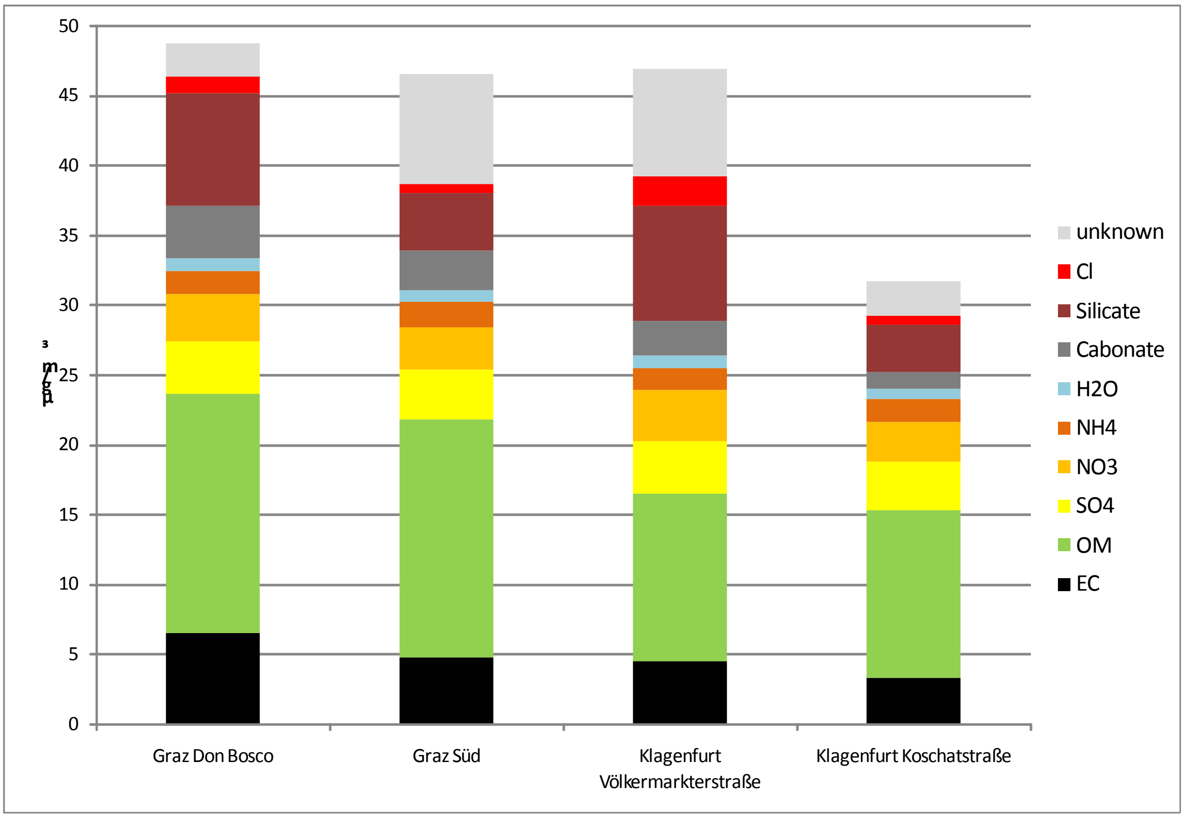

Figure 4: Chemical composition of PM_{10} in Graz (2004) and Klagenfurt (2005) (source: AQUELLA project)

Table 6 gives averages of PM_{10} concentrations and fractions of silicate, carbonate and chloride for winter and summer, separated into PM_{10} daily mean values below and above 50 µg/m³. In this table, winter refers to the period from November to March (as opposed to the usual period from October to March), the period during which winter sanding or salting may occur (in October, usually no snowfall occurs in Austria).

Table 6: Average concentrations of PM_{10}, percentage fraction of silicate, carbonate and chloride. winter period: November – March, summer period: April – October

City	Site (name, EoI code)	Period	Subperiod	PM_{10} (µg/m³)	Silicate (%)	Carbonate (%)	Chloride (%)
Graz	Don Bosco (AT0205A) (traffic)	2004	Summer, <50 µg/m³	28	19	8	0
			Summer, >50 µg/m³	67	17	7	0
			Winter, <50 µg/m³	34	21	10	3
			Winter, >50 µg/m³	81	16	8	4

City	Site (name, EoI code)	Period	Subperiod	PM_{10} (µg/m³)	Silicate (%)	Carbonate (%)	Chloride (%)
Klagenfurt	Völkermarkterstr. (AT0170A) (traffic)	Dec. 2004 – July 2005	Summer, <50 µg/m³ [21]	24	20	5	0
			Winter, <50 µg/m³	36	22	6	3
			Winter, >50 µg/m³	70	15	5	6
Linz	Neue Welt (AT0039A) (traffic, industrial)	April 2005 – Jan. 2006	Summer, <50 µg/m³	26	17	1	0
			Summer, >50 µg/m³	52	16	2	0
			Winter, <50 µg/m³	30	4	1	2
			Winter, >50 µg/m³	66	4	0	1
Linz	Römerberg (AT0183A) (traffic)	April 2005 – Jan. 2006	Summer, <50 µg/m³	30	15	1	0
			Summer, >50 µg/m³	64	16	2	1
			Winter, <50 µg/m³	31	5	1	3
			Winter, >50 µg/m³	77	5	1	3
Salzburg	Rudolfsplatz (AT0038A) (traffic)	2004	Summer, <50 µg/m³ [21]	25	17	6	<0.5 %
			Winter, <50 µg/m³	33	10	7	0
			Winter, >50 µg/m³	65	17	10	0
Wien	Spittelauer Lände (traffic)	Nov. 1999 – Oct. 2000	Summer, <50 µg/m³	32			0
			Summer,	65			0

[21] No daily average PM_{10} values > 50 µg/m³ in summer

City	Site (name, EoI code)	Period	Subperiod	PM_{10} (µg/m³)	Silicate (%)	Carbonate (%)	Chloride (%)
			<50 µg/m³				
			Winter, <50 µg/m³	32			2
			Winter, <50 µg/m³	92			2

Table 7 gives the reduction of the number of days exceeding the daily mean concentration of 50 µg/m³ at some Austrian PM_{10} monitoring sites when NaCl concentrations are subtracted.

Table 7: Number of exceedances of 50 µg/m³ (daily mean concentration) at some Austrian PM_{10} monitoring sites when NaCl concentrations are subtracted

Measuring station (name, EoI code)	Period	Original	Reduced
Graz Don Bosco (AT0205A)	2004	82	76
Klagenfurt Völkermarkterstraße (AT0170A)	Winter 2005/06	75	66
Linz Römerberg (AT0183A)	Winter 2004/05	53	52

A3.1 Graz Don Bosco (EoI code AT0205A)

Information about salting (no sand is used) near the monitoring site Graz Don Bosco is available for the winter months 2004, see Table 8.

Table 8: Average PM_{10} and chloride concentrations for days with and without salting in Graz Don Bosco, 2004

		PM_{10} (µg/m³)	Chloride (µg/m³)
Salting	All days	69	3.1
	PM_{10}>50µg/m³	81	3.7
No salting	All days	55	1.6
	PM_{10}>50 µg/m³	80	2.4

Chloride concentrations are about twice as high on days with winter salting; the difference to days without salting is less for days with PM_{10} concentrations above 50 µg/m³. The average chloride concentration is 4 % of the total PM_{10} on days with winter salting and 3 % on days without salting. The subtraction of NaCl from the PM_{10} concentration at Graz Don Bosco reduces the number of days above 50 µg/m³ in the winter months 2004 from 82 to 76 days.

A3.2 Klagenfurt Völkermarkterstraße (EoI code AT0170A)

Highest values: Chloride averaged over 15-20/1/2005 19 %, 23-24/1, 29-31/1/2005 18 %. Since chemical analyses are averaged over several days, an exact relation between salting and chloride concentration could not be derived from this data set however approximation based on averaged data has been used to quantify the impact of sanding activities on days in exceedance. The subtraction of NaCl from the PM_{10} concentration at Klagenfurt Völkermarkterstraße reduces the number of days above 50 µg/m³ from 75 to 66 days. The highest values of chloride were found at that station. The contribution of chloride to PM_{10} was 19 % on 15-20 January and 18 % on 23-24 as well as 29-31 January 2005. The total number of days considered in this winter period was 162.

A4 Modelling

The Directive 2008/50/EC does not distinguish between exceedances assessed by measurements or modelling as regards the application of Article 21. Therefore the calculated winter sanding/ salting contributions can in principle be used. Different models have been developed to estimate the contribution from winter sanding on observed PM_{10} levels, which can be divided roughly into two approaches:

- modelling of emissions from (re-)suspension (e.g. EPA 2003) and numerical dispersion modelling;

- indirect models, which use statistical relations between observed parameters, like PM_{10} concentrations at different measuring stations, meteorological parameters, etc. (e.g. STEIERMARK 2008).

A combination of both approaches has been developed e.g. in Slovakia (SZABÓ & HDRINA, 2007).

As indicated in the main text, the currently assessed modelling-based approaches were not able to satisfy the identified key principles and continue to be a matter of further development.

A4.1 Procedure for reduction in Slovakia

According to the information provided by the Slovak Hydrometeorolgical Institute (SZABÓ & HDRINA, 2007; personal communication by G. Szabó), various approaches have been tested to estimate the influence of winter sanding on PM_{10} daily mean values above 50 µg/m³:

- comparison of kerbside and background stations during a cold winter with intense winter sanding (2005/06) and a warm winter with almost no winter sanding (2006/07);

- modelling (re)suspension of sanding gravel using the CEMOD model;

- a simple modelling approach, based on EPA (2003), which uses information about traffic characteristics, dust load on the road and street geometry.

The documentation was short and did not allow a thorough scientific assessment. The method was still in the state of development. No information about the validation of the various approaches can be provided at present.

A4.2 *Further modelling approaches*

Research on re-suspension due to winter sanding is pursued in Finland (KUPIAINEN 2007). Kupiainen uses the CMB (Chemical Mass Balance) software from US EPA, based on the mineralogy of the road dust. The method has been applied under laboratory conditions.

OMSTEDT ET AL. (2005) developed a model which considers specific factors influencing non-exhaust emissions from road traffic. Besides the rather constant emissions from tyre, break and road wear, day-to-day variations of the dust layer on the road, the PM_{10} emissions by (re)suspension and PM_{10} concentrations are attributed to:

- road surface conditions (dry – wet), which by itself is influenced by precipitation;
- number of cars equipped with studded tyres;
- sanding for traction control.

The model was tested for a street canyon in Stockholm and a highway outside the city.

Modelling the suspension of road dust including gravel from winter sanding was also applied in Graz (STEIERMARK 2008), where quite satisfying results have been obtained by calculating the monthly mean contribution from (re)suspension using measurement data from different types of measuring stations. However, model results on a daily basis were far from being realistic.

ANNEX B EXAMPLE OF A REPORT ON QUANTIFICATION OF WINTER SANDING CONTRIBUTION TO 20XX EXCEEDANCES (2008/50/EC ARTICLE 21)

B1. Aim and scope

This document aims at providing information and evidences to demonstrate that the exceedance situations monitored in the EU0001 air quality zone are due to the re-suspension of particulates following winter sanding of roads.

B2. Body designated– competent authority

Member State:

Name of the contact body:

Postal address:

Name of contact person:

Telephone of contact person:

Fax of contact person:

E-mail address of contact person:

Reference Year:

B3. Short description of the exceedance situations attributable to winter sanding

In 2009 exceedances of the PM_{10} daily limit value have been monitored in two traffic-oriented measuring stations in the XX0001 agglomeration. These measuring stations are sited along the following two busy roads:

1. XX0011 city ring (>250.000 vehicles/day).
2. XX0014 Central street (>40.000 vehicles/day with street canyon configuration).

The exceedance of the PM_{10} daily limit value in these two stations can be attributed to the re-suspension of particulates following winter sanding of roads as it has been reported in Form 24A of the annual reporting questionnaire set up by decision 2004/461/EC and as it is shown in *Table 9*.

Table 9: Form 24a Contribution of winter sanding to exceedances of the PM_{10} limit value

Zone	EoI station code	Number of exceedences measured	Estimated number of exceedences after subtraction of winter sanding contribution	Reference to justification
XX0001	XX0011 - Ring	55	35	Report on quantification of winter sanding contribution to 20XX exceedances
XX0001	XX0014 – Central street	43	23	

B4. Short description of the procedure used to determine the contributions from the re-suspension of particulates following winter sanding

The procedure suggested in the guidance on assessing the contribution of winter sanding or –salting under the Directive 2008/50/EC has been used to quantify the impact of winter sanding

The proposed method assumes the contribution from winter sanding to be 50 % of the coarse fraction (PM_{10}-$PM_{2.5}$) for each exceedance day. This contribution can be subtracted from the observed PM_{10} concentration if the following criteria apply:

1. Winter sanding activities have taken place, and there was road sand or the remains of it actually on the road or adjacent footpaths.

2. The road surface was dry.

3. The $PM_{2.5}/PM_{10}$ ratio is equal or less than 0.5. This criterion selects days with high local contributions of coarse particles and excludes high contributions from long-range transport (both values have to be from the same measurement station or within respective areas of representativeness).

B5. Evidences demonstrating that the exceedance situations are due to the re-suspension of particulates following winter sanding of roads

In Table 3 the following information supporting the winter sanding claim is reported:

- Column 1 and 2: month and day in which exceedance of the daily average concentration of 50 $\mu g/m^3$ occurred.

- Column 3: daily PM_{10}concentrations measured in the XX0011 measuring station.

- Column 4: daily PM_{10} concentrations measured in the XX0014 measuring station.

- Column 5: presence of sanding activities, information in this column shows the fulfilment of 1st condition.

- Column 6: indication of the conditions of the roads surface, information in this column shows the fulfilment of 2nd condition.

- Column 7: $PM_{2.5}$ data monitored at XX0011 - Ring measuring station used to calculate the winter sanding contribution and the $PM_{2.5}/PM_{10}$ ratio for this station

- Column 8: $PM_{2.5}$ data monitored at XX0017 – Urban background station used to calculate the winter sanding contribution and the $PM_{2.5}/PM_{10}$ ratio for XX0014 – Central street measuring station since $PM_{2.5}$ is not measured there.

- Columns 9-12 indication of presence of long range transport phenomena. In these columns are reported:

  – The PM2.5/PM10 ratio for each exceeding station (9-10).

- Confirmation of the presence o long range transport carried out with backward trajectories analysis (11). Data from rural background stations can also be used as an indicator of the presence of long range transport.

- A summary column showing the fulfilment of the 3rd condition (12).

- Columns 13: summary column showing the simultaneously fulfilment of the 3 conditions. The deduction is carried out only in those days that, fulfilling at the same time the 3 conditions, have been considered eligible for deduction.

- Column 14: PM_{10} concentrations attributable to winter sanding at XX0011 measuring station (50 % of the coarse fraction PM_{10}-$PM_{2.5}$).

- Column 15: PM_{10} concentrations attributable to winter sanding at XX0014 measuring station (50 % of the coarse fraction PM_{10}-$PM_{2.5}$).

- Column 16: PM_{10} net concentrations at XX0011 measuring station.

- Column 17: PM_{10} net concentrations at XX0014 measuring station.

B6. Conclusions

The estimated number of days in exceedance after subtraction of winter sanding contribution is 35 at XX0011 measuring station and 23 at XX0014 measuring station.

Table 10: Evidences demonstrating that the exceedance situations are due to the re-suspension of particulates following winter sanding of roads

(1) Month	(2) Day of month	(3) XX0011 PM_{10} level ($\mu g/m^3$)	(4) XX0014 PM_{10} level ($\mu g/m^3$)	(5) Presence of sanding activities	(6) Road surface dry	(7) XX0011 $PM_{2.5}$ level ($\mu g/m^3$)	(8) XX0017 $PM_{2.5}$ evel ($\mu g/m^3$)	(9) Indications for long-range transport $PM_{2.5}/PM_{10}$ ratio	(10) Indications for long-range transport $PM_{2.5}/PM_{10}$ ratio	(11) confirmation for long-range transport	(12) Days affected by long range transport	(13) Days eligible for deduction.	(14) XX0011 contribution attributable to ws ($\mu g/m^3$)	(15) XX0014 contribution attributable to ws ($\mu g/m^3$)	(16) XX0011 net PM_{10} concentration ($\mu g/m^3$)	(17) XX0014net PM_{10} concentration ($\mu g/m^3$)
1	22	61	54	y	y	22	19	0.36	0.35		n	y	20	18	42	37
1	23	62	52	y	y	28	25	0.45	0.48		n	y	17	14	45	39
1	24	56		y	y	26	23	0.47		n	n	y	15		41	
1	25		60	y	y	18	18		0.30	n	n	y		21		39
2	1	64	55	y	y	22	20	0.34	0.36	y	n	y	21	18	43	38
2	13	59	54	y	y	33	29	0.56	0.54	y	y	n			59	54
2	14	69	64	y	y	35	33	0.51	0.52	y	y	n			69	64
2	15	84	70	y	y	33	30	0.39	0.43	n	n	y	26	20	59	50
2	26	60		y	y	23	18	0.38		n	n	y	19		42	
2	27	60	61	y	y	20	19	0.33	0.31	n	n	y	20	21	40	40
3	5	64	54	y	y	22	22	0.34	0.41		n	y	21	16	43	38
3	14	52		y	n	18	19	0.35			n	n			52	
3	28	52		y	n	16	13	0.31			n	n			52	
3	29	63	58	y	y	21	18	0.34	0.31		n	y	21	20	42	38
4	1	89	70	y	y	25	19	0.28	0.27		n	y	32	26	57	45
4	2	113	100	y	y	24	22	0.21	0.22		n	y	45	39	69	61
4	3	65	59	y	y	21	23	0.32	0.39		n	y	22	18	43	41
4	4	68	61	y	y	25	23	0.37	0.38		n	y	22	19	47	42
4	6	65	58	y	y	18	14	0.28	0.24		n	y	23	22	41	36

(1) Month	(2) Day of month	(3) XX0011 PM_{10} level ($\mu g/m^3$)	(4) XX0014 PM_{10} level ($\mu g/m^3$)	(5) Presence of sanding activities	(6) Road surface dry	(7) XX0011 $PM_{2.5}$ level ($\mu g/m^3$)	(8) XX0017 $PM_{2.5}$ evel ($\mu g/m^3$)	(9) Indications for long-range transport $PM_{2.5}/PM_{10}$ ratio	(10) Indications for long-range transport $PM_{2.5}/PM_{10}$ ratio	(11) confirmation for long-range transport	(12) Days affected by long range transport	(13) Days eligible for deduction.	(14) XX0011 contribution attributable to ws ($\mu g/m^3$)	(15) XX0014 contribution attributable to ws ($\mu g/m^3$)	(16) XX0011 net PM_{10} concentration ($\mu g/m^3$)	(17) XX0014net PM_{10} concentration ($\mu g/m^3$)
4	7	53	59	y	y	19	18	0.36	0.31		n	y	17	21	36	39
4	16	58		y	n	20	17	0.35			n	n			58	
4	25	71	67	n	y	27	24	0.38	0.36		n	n			71	67
4	28	56		n	y	26	23	0.47			n	n			56	
6	7	76	59	n	y	33	28	0.43	0.47		n	n			76	59
6	10	64		n	n	28	26	0.44			n	n			64	
6	11	60		n	n	22	20	0.37			n	n			60	
6	12	70	75	n	n	17	14	0.24	0.19		n	n			70	75
6	20	55	62	n	y	19	16	0.35	0.26		n	n			55	62
6	21	67	53	n	y	16	15	0.24	0.28		n	n			67	53
6	25	57		n	n	25	22	0.43			n	n			57	
6	26	53		n	n	24	20	0.45			n	n			53	
6	28		52	n	n	26	24		0.46		n	n				52
7	22	80	73	n	y	28	25	0.35	0.34		n	n			80	73
7	24	54		n	y	24	28	0.45			n	n			54	
7	30		55	n	y	18	15		0.27		n	n			0	55
8	2	58	52	n	y	15	12	0.26	0.23		n	n			58	52
8	4	61	60	n	y	14	15	0.23	0.25		n	n			61	60
8	5	55		n	y	16	13	0.29			n	n			55	
9	25	70		n	n	18	16	0.26			n	n			70	
9	26	65	55	n	n	23	20	0.35	0.36		n	n			65	55

(1) Month	(2) Day of month	(3) XX0011 PM_{10} level ($\mu g/m^3$)	(4) XX0014 PM_{10} level ($\mu g/m^3$)	(5) Presence of sanding activities	(6) Road surface dry	(7) XX0011 $PM_{2.5}$ level ($\mu g/m^3$)	(8) XX0017 $PM_{2.5}$ evel ($\mu g/m^3$)	(9) Indications for long-range transport $PM_{2.5}/PM_{10}$ ratio	(10) Indications for long-range transport $PM_{2.5}/PM_{10}$ ratio	(11) confirmation for long-range transport	(12) Days affected by long range transport	(13) Days eligible for deduction.	(14) XX0011 contribution attributable to ws ($\mu g/m^3$)	(15) XX0014 contribution attributable to ws ($\mu g/m^3$)	(16) XX0011 net PM_{10} concentration ($\mu g/m^3$)	(17) XX0014net PM_{10} concentration ($\mu g/m^3$)
10	11	67	53	n	y	21	18	0.31	0.34		n	n			67	53
10	20	75	76	y	y	18	15	0.24	0.20	n	n	y	29	31	47	46
10	21	103	90	y	y	22	20	0.21	0.22	n	n	y	41	35	63	55
11	14	80	72	y	y	35	32	0.44	0.44	y	n	y	23	20	58	52
11	15	67	65	y	y	35	35	0.52	0.54	y	y	n			67	65
11	17	54	52	y	y	30	33	0.56	0.63	y	y	n			54	52
11	18	59	58	y	y	18	15	0.30	0.26	n	n	y	21	22	39	37
11	19	116	98	y	y	15	12	0.13	0.12	n	n	y	50	43	65	55
11	20	88	78	y	y	18	19	0.20	0.24	n	n	y	35	30	53	49
11	21	82		y	y	22	18	0.27			n	y	30		52	
11	22		56	y	n	27	24		0.43		n	n				56
12	19	60	52	y	n	24	19	0.40	0.37		n	n			60	52
12	20	52	71	y	y	20	15	0.38	0.21		n	y	16	28	36	43
12	22	59		y	y	16	16	0.27			n	y	22		38	
12	23	57		y	y	26	22	0.45			n	y	16		42	
12	24	56	54	y	n	18	15	0.32	0.28		n	n			56	54
12	25		69	y	y	22	21		0.30		n	y		24		45
12	26	72		y	y	24	19	0.33			n	y	24		48	
12	27	74	70	y	y	18	15	0.24	0.21		n	y	28	28	46	43
12	30	72	59	y	y	12	15	0.17	0.25		n	y	30	22	42	37