

Determination of the 99.8-Percentile of NO₂ Concentrations and PM₁₀ Emissions for EIA Studies

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1. Introduction

The EU Council Directive 1999/30/EC of 22 April 1999 includes NO₂ and PM₁₀ as air pollutants and sets limit values for the protection of human health. The limit value for NO₂ is 200 µg/m³ not to be exceeded more than 18 hours in a calendar year (that is approximately the 99.8-percentile) and an annual limit value of 40 µg/m³, both values to be achieved by the year 2010. There is also a "stage I" objective for PM₁₀ of the 24-hour limit value of 50 µg/m³, not to be exceeded more than 35 times a calendar year (approximately the 90- percentile), with an annual limit value of 40 µg/m³, both to be achieved by 1 January 2005. Thus, for an Environmental Impact Assessment, the concentrations of NO₂ and PM₁₀ have to be predicted.

2. Determination of the 99.8 percentile of the NO₂ concentrations

For conventional dispersion calculations the input as time series of wind, emission, background concentration, NO-NO₂-conversion parameters, etc. are generally not in a quality allowing the determination of the 99.8-percentile [Clai et al., 2001]. Even field measurements show being very coincidental if they are evaluated for a single calendar year only. In December 1996 and January 1997, caused by extreme meteorological conditions, nearly all monitoring stations in the Southern German states of Hessen and Bavaria showed unexpected high 99.8-percentiles. See Figure 1 with the results of the measurements in Viernheim as an example. These results can not be predicted by regular operational dispersion modelling used for EIA studies.

But field measurements also show there is a fair correlation between the annual mean or preferably the 98- and the 99.8-percentile of NO₂ [Lohmeyer et al., 2000] if such exceptional years as 1997 are excluded. See Figure 2 for the case of the annual mean on the basis of more than 700 one-year-time-series. For the 98-percentile the correlation is even better. Therefore, to deal with the 99.8-percentile, it is proposed to calculate the annual mean value or the 98-percentile in the conventional way and then deduct the 99.8-percentile by figures like Figure 2: In case the annual mean is calculated by dispersion modelling for operational purposes, Figure 2 indicates that the probability of exceedance of a 99.8-percentile of 200 µg/m³ is small, if the annual mean is smaller than 40 µg/m³.

Figure 2 also indicates, that the limit value in EU Directive 1999/30/EU of 40 µg/m³ for the annual mean of NO₂ is harder than the limit for the 99.8-percentile as many monitoring stations show an exceedance of 40 µg/m³ in the annual mean more than an exceedance of 200 µg/m³ in the 99.8-percentile. Thus for operational purposes it might be enough to show, that the annual mean is below the limit value.

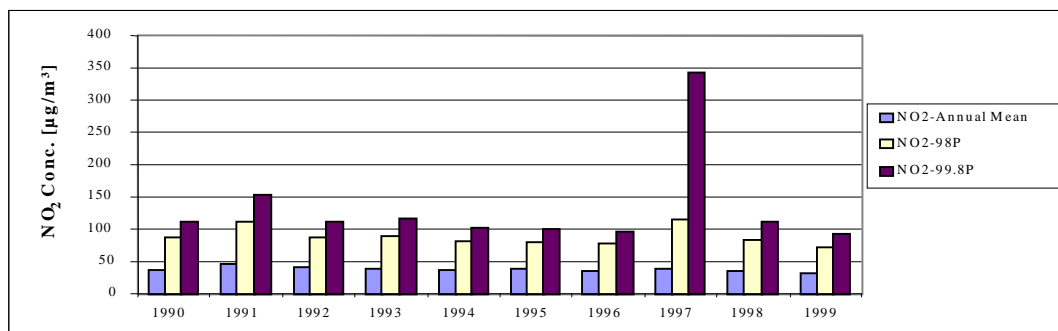


Figure 1: Field data for several years at monitoring station in Viernheim

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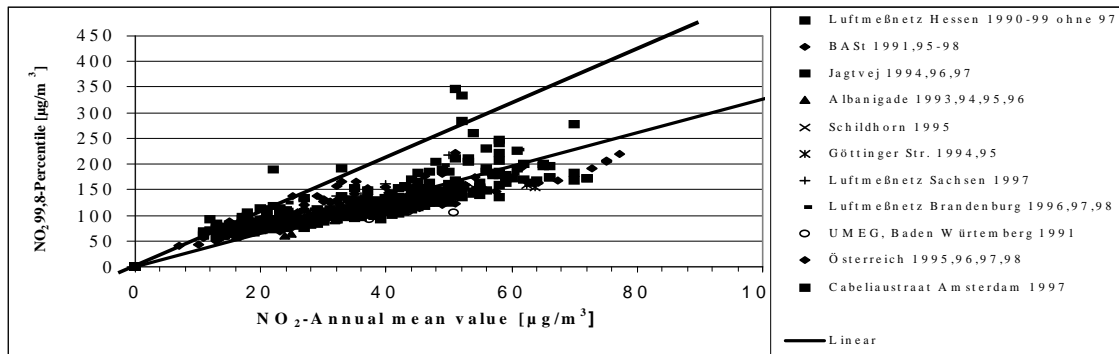


Figure 2: 99.8-percentile as function of the annual mean

3. Determination of the PM₁₀Emission

In the case of PM₁₀ concentration, there is not a general consensus of how to predict the emission. Several studies [Hueglin et al., 2000; Heldstab et al., 1999; EPA AP-42, 1993, 1997] have shown that the main factor on the emission of PM₁₀ particles from paved roads is the emission of the loose material on the surface of the road by the traffic turbulent flux. Other sources of PM₁₀ emission come directly from the exhaust pipe and the decomposition of tires and brakes. There is comparatively good information on the contribution coming out of the exhaust pipe, but the most important contribution coming from abrasion from the road does not seem to be satisfactorily known. It seems that the most extended model, the EPA model, is not suitable to describe the PM₁₀ emission from paved roads. One of the main rejections that can be pointed out is the selection of parameters. In particular, the silt load does not seem to be a good choice from the theoretical point of view (see, for example, Venkatram 2000) and also from the experimental one (the predicted and the observed emission vary a lot; see, for example, Venkatram 2000). In this report, we will try to describe which the plausible sources of PM₁₀ are and justify the disregarding of the silt load term as parameter.

3.1 Why the silt load is not a good parameter?

Our first argument is that the mass of the silt load deposited on a paved road is small compared to the mass emitted by this road per unit time. Let us take as an example a paved street ten meters wide and one thousand meters long. Let us suppose that a certain number of vehicles per day, some of them trucks, use the street in several lanes. Let us assume there is wind blowing at a certain speed (so, re-deposition is not allowed) and perpendicular to the road all day long and let us assume there is no input to the road from "irregular sources" like litter, spills, dirt carryout, etc.. The EPA formula gives for that condition in dry days a PM₁₀ emission of about 0.25 g/VKT (grams per vehicle and kilometre travelled). Several studies estimate that the contribution from the exhaust pipe, tire and brakes is less than 50% of the total. Where does the rest of the mass come from? Can it be delivered from the silt load of the road? To answer this question, we have two possibilities. First, if the silt load term is supposed to be infinite compared to the material emitted per unit time, i.e. much higher, then the emission might come from the hypothetical silt load reservoir, but let us make some numbers. Let us just compare the pure mass of the silt load (PM₇₅) to the mass (PM₁₀) emitted by the road per day without considering the different particle sizes and get approximate numbers of the masses involved in the process. Let us assume for our example the default silt load value of the US EPA for streets with high average daily traffic, that is 0.1 g/m², thus the total silt load of the road is 10m × 1000m × 0.1 g/m²=1000 g. Let us suppose that the silt load should be about 100 times higher than the PM₁₀ emitted for our purpose of considering it infinite. How many vehicles are then needed to emit 10 g of PM₁₀ in one day? An easy estimation shows only 40 vehicles. If the number is much higher, and it is the case in the majority of roads, the first assumption is shown by that not to be reasonable. Let us suppose then that the silt load term is finite compared to the material emitted per unit time, meaning it

is not much higher, then it is not reasonable to assume that the amount of material on the road is able to deliver in the long run the material that is emitted into the air unless you have a permanent source of silt load, and the only permanent and universal source (permanent in the sense of "during all the time the process is occurring", and universal in the sense that "is valid for all the paved roads") are the atmospheric dust and the abrasion of the road due to traffic, and not the silt load. Can it be that the regular atmospheric deposition of dust replenishes the silt load of the road continuously, thus enabling the silt load to provide the masses we need for emission? In Germany, a common value for the dust deposition is about $0.1 \text{ g}/(\text{m}^2 \text{ day})$, thus on the road a mass of $10\text{m} \times 1000\text{m} \times 0.1 \text{ g} / \text{m}^2 = 1000 \text{ g}$ are deposited per day. Then we see that this mass flow is not big enough to replenish the silt load. So, our steps lead us to consider the abrasion of the road as one of the main sources of PM_{10} emission. In the next section estimations supporting this conclusion will be made.

Our second argument supporting the idea that the silt load is not a good parameter is the effect of sweeping the street. A report [Fitz, 1998] shows that the effect of sweeping diminishes the silt load value but has no measurable effect on the PM_{10} emission and this is a clear support of our above-mentioned argument.

Finally, the third argument is simply the following: there is a high uncertainty when using the EPA formula with the silt load as parameter, both in the statistical database used to develop the emission factor and in the subsequent application to real streets. So, for all the reasons explained above, the statement that the silt load is not a good parameter is, in our opinion, well supported.

Until now, we have said that the EPA model is not good, but we have not offered other possibilities. In the following paragraphs, we will try, at least, to justify the selection of other possible parameters.

3.2 Are there better parameters for PM_{10} emission?

In the last section, we pointed to the abrasion of the street as one of the main sources of PM_{10} emission. Now, we will try to justify this assumption. There is presently no general consensus on the amount of material abraded from a road when a vehicle passes on it. Information varies from about 10^3 m per year for freeways [Muschak, 1990] to about $10^3 \text{ m}/10^6 \text{ vehicles}$ [Sieker and Grottker, 1988]. Taking these amounts as example, and a daily traffic volume of 40000 vehicles/day for the number of Muschak, the total volume abraded in our sample street is $0.7 \text{ m}^3/10^6 \text{ VKT}$ (Muschak) to $10 \text{ m}^3/10^6 \text{ VKT}$ (Sieker). Let us take a typical density of $2.5 \times 10^6 \text{ g}/\text{m}^3$. So the total mass abraded is, approximately, $M=1.5 \text{ to } 25 \text{ g}/\text{VKT}$. This amount is containing particles of all sizes, but we have no information on the distribution of these sizes. Nevertheless, if it is compared to the 0.1 to 0.2 g/VKT we are looking for, the abrasion seems to produce enough material to justify the assumption that it is the important missing part in the production of the PM_{10} emission, we are looking for.

In Figure 3, estimations taken from the literature are shown. It can be seen that the idea is that, roughly, all the particle income is emitted and the silt load is not a parameter needed for mass conservation.

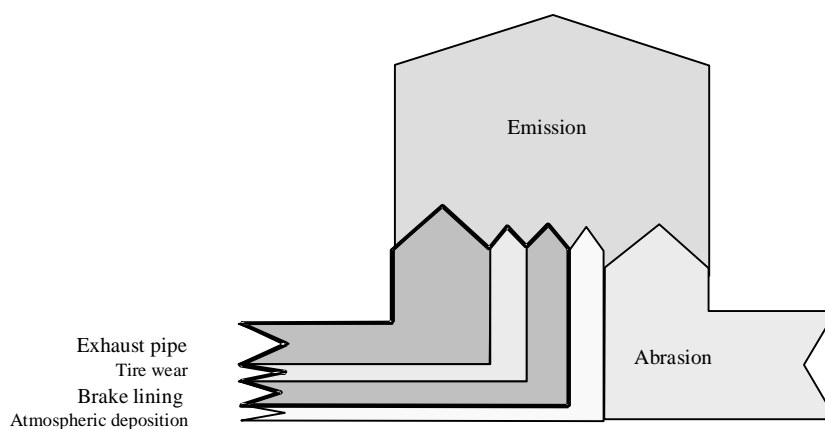


Figure 3: PM_{10} mass flow on the high traffic loaded road under consideration and incoming mass flow, allowing for the conservation of mass of the system. The silt load is not relevant for our example in section 3.1

3.3 Conclusion

We presently cannot offer a better model than the EPA model. But, as we pointed out, if we want to make things better, we should not concentrate on the silt load as an input parameter and play around with it. For paved roads (not for unpaved roads) that can only be a second order parameter. We have to concentrate on the abrasion processes and the parameters determining that. That might be:

- a) kind of the material (asphalt, concrete, etc) of the road surface
- b) state of the road surface (smooth or rough, good condition or cracked...)
- c) speed of the vehicles (additionally to the weight)
- d) etc...

BIBLIOGRAPHY

Clai, G., R. Berkowicz, I. Düring, M. Ketzel, A. Lohmeyer, N. Moussiopoulos and S. Papalexioiu (2001): Proposal for the calculation of the high percentiles of concentrations, necessary for the execution of directive 1999/30/EU. Accepted for publication in a special issue of the IJEP journal.

EPA (1993,1997): Emission Factor Documentation for AP-42, Section 13.2.1. Paved Roads. <http://www.epa.gov/ttn/chief/ap42/ch13/>.

EU Council Directive 1999/30/EC (22 April 1999): Official Journal of the EU. L **163**/41-60.

Fitz, D. R. (1998): Evaluation of street sweeping as a PM₁₀ control method. Center for environmental research and technology, College of Engineering. University of California. Prepared for the Mobile Source Air Pollution Review Committee.

Heldstab, J., Künyle, T., de Haan, P., Keller, M. (1999): Modellierung der PM₁₀-Belastung in der Schweiz. BUWAL Schriftenreihe umwelt **310**.

Hueglin, C., Gehrig, R., Hofer, P., Monn, C., Baltensperger, U. (2000): Partikelemissionen (PM₁₀ und PM_{2,5}) des Straßenverkehrs. Chemische Zusammensetzung des Feinstaubes und Quellenzuordnung mit einem Rezeptormodell. Bericht des NFP41 "Verkehr und Umwelt", Bericht C4. EMPA, Abt. Luftfremdstoffe / Umwelttechnik, Dübendorf.

Lohmeyer, A., Nagel, T., Clai, G., Düring, I., Öttl, D. (2000): Bestimmung von Kurzzeitbelastungswerten - Immissionen gut vorhergesagt. In: Umwelt (kommunale ökologische Briefe) Nr. 01/05.01/2000.

Muschak, W. (1990): Pollution of street run-off by traffic and local conditions. The science of the Total Environment, 93, 419-431.

Sieker, F.; Grottker, M. (1988): Beschaffenheit von Straßenoberflächenwasser bei mittlerer Verkehrsbelastung. Forschung Straßenbau und Straßenverkehrstechnik, Heft 530, 1988. Hrsg. Bundesminister für Verkehr, Abt. Straßenbau, Bonn-Bad Godesberg.

Venkatram, A. (2000): A critique of empirical emission factor models: a case study of the AP-42 model for estimating PM₁₀ emissions from paved roads. *Atmospheric Environment*. **34**, 1-11.

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