The effect of particle filters on HDV in Denmark

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Summary

An investigation was requested by the Danish Traffic Agency as part of the basis for decisions on mandatory installation of particle filters on heavy duty vehicles in Denmark. The investigation was based on already available data.

The overall objective of the investigation was to assess the health effects of installation of particle filters with an efficiency of 80% on all heavy-duty diesel vehicles (> 3.5 tons) in Denmark.

Many studies in United States and Europe have shown that particles give rise to adverse health effects, and most of the studies focused on PM_{10} and $PM_{2.5}$ (slides 3-4). It is unclear, which properties of the particles are important, but some studies indicate that the very small particles (fine and ultrafine) are the most hazardous. The assessment of the adverse health effects has been based on the above studies of the effect of PM_{10} and $PM_{2.5}$. In addition, an assessment of the adverse health effects of ultrafine particles has been attempted. The consequence of installing filters on all heavy-duty vehicles in Denmark has been estimated.

Model calculations and data analysis were used to determine the traffic contribution to PM_{10} in Danish cities. The model calculations were carried out for Copenhagen, where the necessary data exist (slide 4). In addition, data from London were used. The PM_{10} levels were estimated on the known relationship between NO_x and PM_{10} from road traffic. The ratio depends on type cars and on driving conditions, but seems to be comparable for London and Copenhagen (slide 5). The generalisation was based on data for NO_x, depending on city size (slide 6-7).

Installation of filters on all heavy-duty vehicles will only reduce the urban background of PM_{10} a little, because the size of diesel particles is small with low mass (slides 7-8). The reductions in streets will be larger, but no risk estimates are available for this type of exposure. Assessments based on PM_{10} result therefore only to very limited positive effects of filters on heavy-duty diesel vehicles. However, because ultrafine particles are believed to be responsible for the major part of the adverse health effects of particles, the effects of filters might be much larger (slide 9-10). Since filters were estimated to reduce the concentration of ultrafine particles with 1/3 in cities the upper limit of the reduction in adverse health effect will be 1/3. The lower estimate is e.g. 30 premature deaths and the upper estimate is 1600. This large interval is not satisfactory for the decision-makers (slide 11).

The long range transported particles contribute significantly to the urban background pollution, but there is a significant contribution from the traffic, which correlates with NO_x, in busy streets (slides 12-13). Application of two different PM_{10} measurement methods (beta-absorption (SM200) and TEOM) shows that approx. 50% of the PM_{10} is volatiles, e.g. NH_4NO_3, organics and water, where NH_4NO_3 mainly is long range trasported (slides 13-15). The contribution with PM_{10} is different in Stockholm, where winter sanding and road wear due to studded tires might be important (slide 16). Preliminary investigations of ultrafine particles are shown in slide 16. Reduced sulphur content in diesel from 500 ppm to less than 50 ppm in Denmark has

lead to reduced formation of nano particles in two winter periods (slide 19). In addition to ambient air measurements we have made some measurement on the efficiency of different particle filters (slide 20).

Much better and long-time series of particle data are necessary for health effect studies. In addition to $PM_{10}/PM_{2.5}$ they must include also information about the size distribution of ultrafine particles and the properties of the particles. In addition, much better emission factors of the road traffic are needed including the above parameters.

References

Palmgren, F., Wåhlin, P., Berkowicz, R., Hertel, O., Jensen, S.S., Loft, S. & Raaschou-Nielsen, O. (2001): Particle filters on heavy duty vehicles in Denmark. Assessment of air quality and health effects. National Environmental Research Institute. 94pp – Technical report from NERI. no 358. (In Danish with executive summary in English)

Palmgren, F., Wåhlin, P., Berkowicz, R. & Van Dingenen, R. (2001). Fine Particles from Traffic. Midgley, P.M., Reuther, M. and Williams M. (Eds.) Proceedings of EUROTRAC Symposium 2000, Garmisch-Partenkirchen, Germany. Springer Munich.

Wåhlin, P., Palmgren, F. & Van Dingenen, R. (2001), Experimental studies of ultrafine particles in streets and the relationship to traffic. Atmospheric Environment. Vol 35/1001, pp S63-S69

Wåhlin, P., Palmgren, F., Van Dingenen, R. & Raes, F. (2001). Pronounced decrease of ambient particle number emissions from diesel traffic in Denmark after reduction of the sulphur content in diesel fuel. Atmospheric Environment. Vol 35/21, pp 3549-3552.

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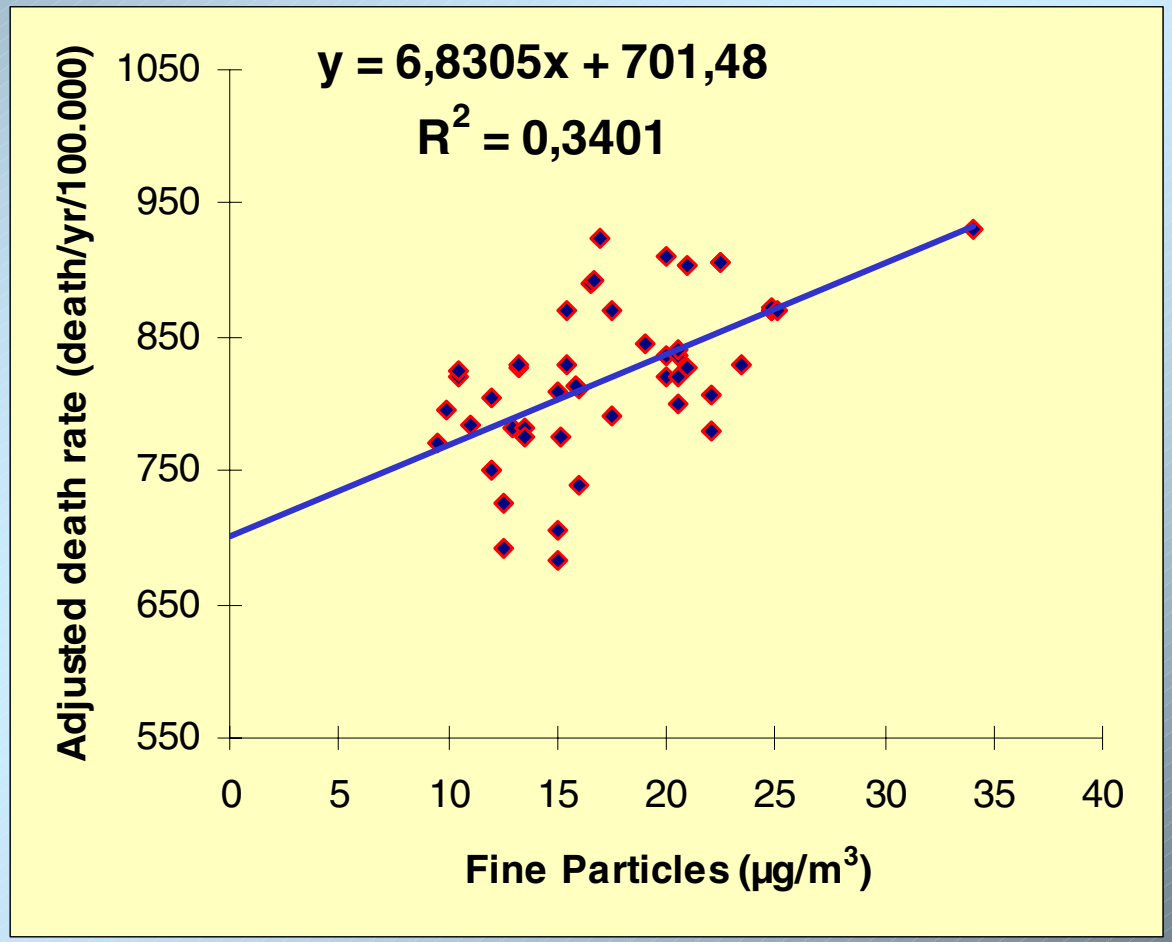
Content of the presentation

- The effect on human exposure with PM_{10} in urban background
- The effect on exposure with ultrafine particles in urban background
- PM in streets
- Conclusions

The effect of filters on HDV in Denmark on human exposure (and health) with particles?

- Assumptions
  - PM_{10} health studies in US (Pope et al. 1995)
  - 80% filter efficiency
  - Exposure (and the US health studies) related to urban background
- Method
  - Estimate the exposure of the population
  - Ultrafine particles?

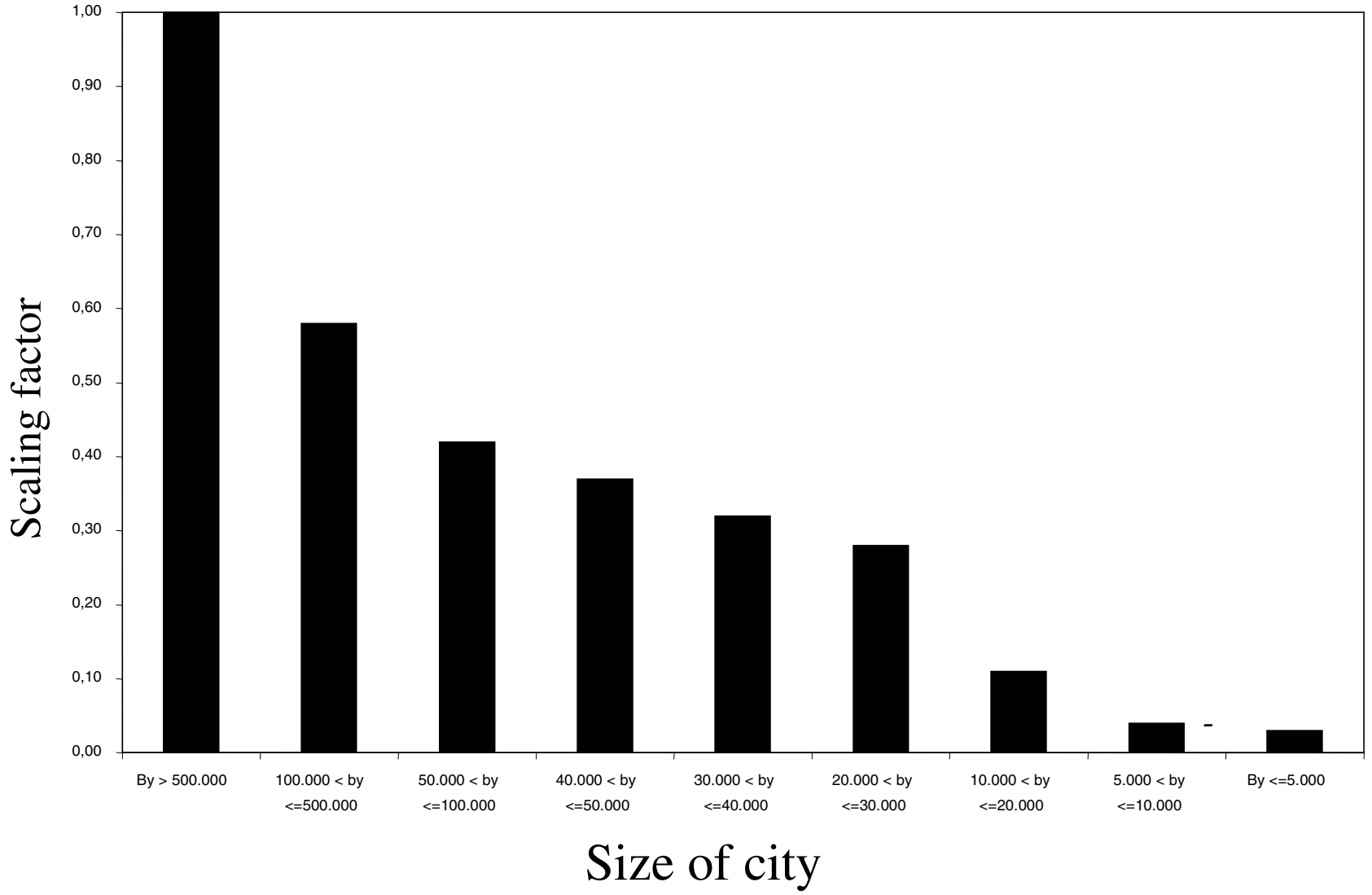
Pope III, C.A., Thun, M.J., Namboodiri, M.M., Dockery, D.W., Evans, J.S., Speizer, E., and Heath Jr., C.J. 1995. Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults. Am. J. Respir. Care Med., 151, 669-674.



Traffic contribution to PM_{10} in urban background in Copenhagen based on PM_{10}/NO_x ratio and NO_x mapping.

Categories:	($\mu g/m^3$)	(%)
Passenger cars	0.24	25
Vans	0.28	28
Lorries	0.36	36
Buses	0.10	11
Total	0.98	100

The regional background is approx. 22 $\mu g/m^3$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100.000 < by <=500.000
50.000 < by <=100.000
40.000 < by <=50.000
30.000 < by <=40.000
20.000 < by <=30.000
10.000 < by <=20.000
5.000 < by <=10.000
By <=5.000
Size of city

Weighted (city size) PM_{10} annual concentration for different scenarios

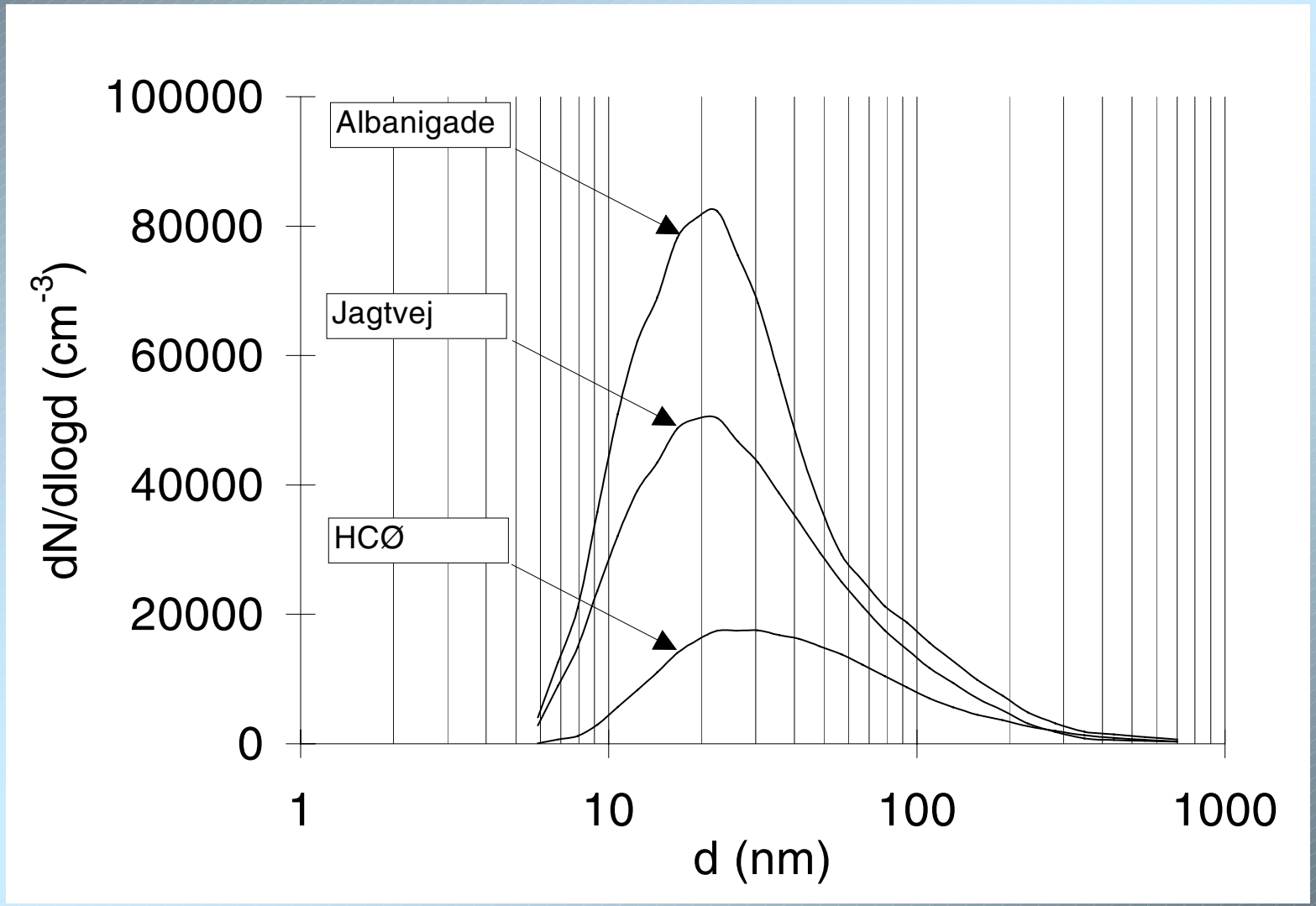
Population	Fraction (%)	Reference year (2000) ($\mu g/m^3$)	Particle filters* on HDV ($\mu g/m^3$)
Urban population	69	22.38	22.24
Rural population	31	22.00	22.00
Total	100	22.26	22.17

**80% filter efficiency*

Why is the effect on PM_{10} of filters so small?

- The regional background is relatively high
- Filters do only remove exhaust particles (not particles from resuspension, tyres, brakes, road etc.)
- Filters can not remove secondary particles

- ***but the filters can remove ultrafine particles (soot/EC), which might be the most hazardous***


100000
80000
60000
40000
20000
0
dN/dlogd (cm-3)
Albanigade
Jagtvej
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1
10
100
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d (nm)

Removal of UF particles by filters

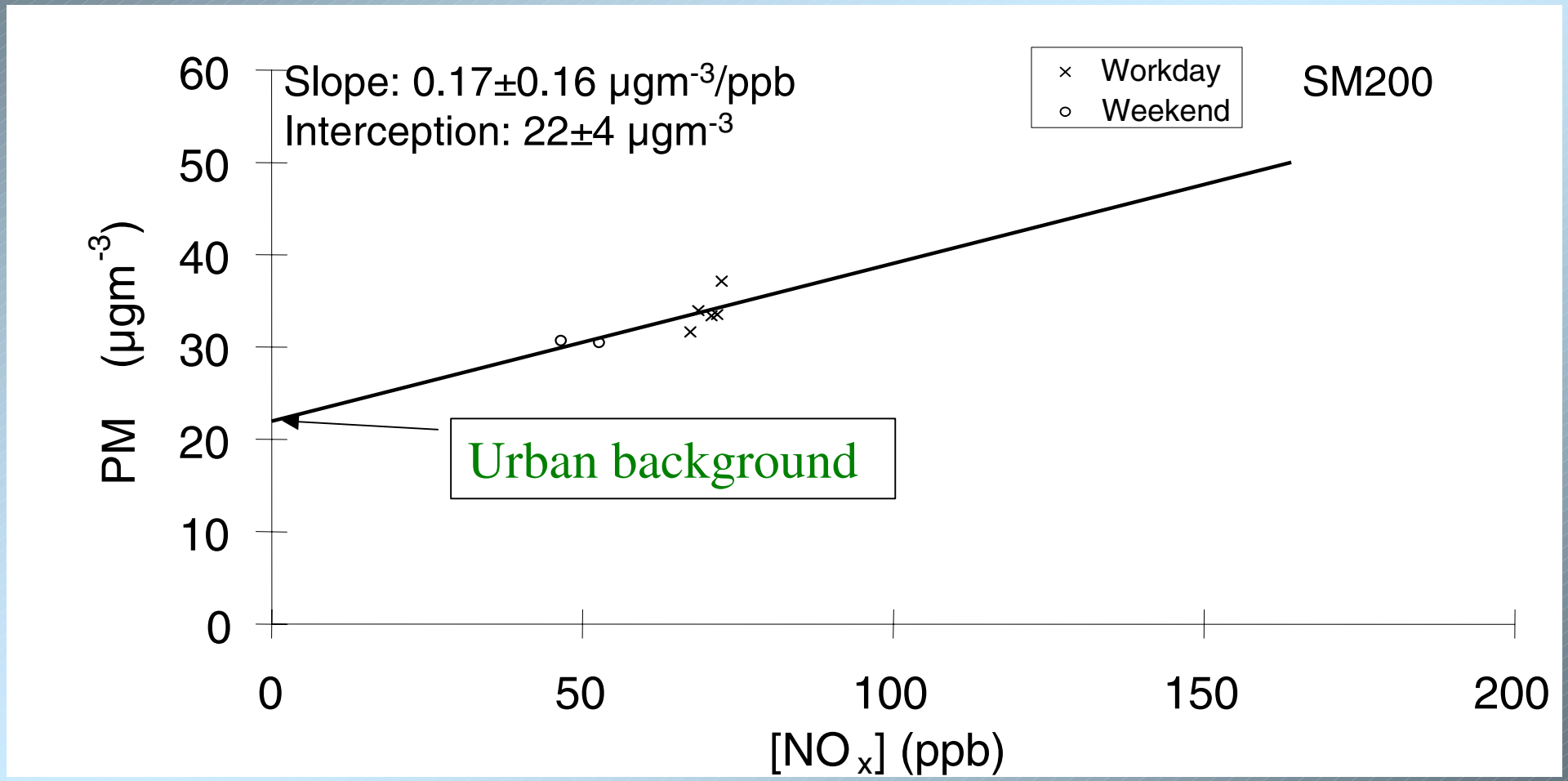
- Using the same technique as for PM_{10}, we found that 20-30% of the UF particles (number) in urban background can be removed by filters on all HDV in Denmark
- New German studies have shown a connection between UF particles and premature death

Results

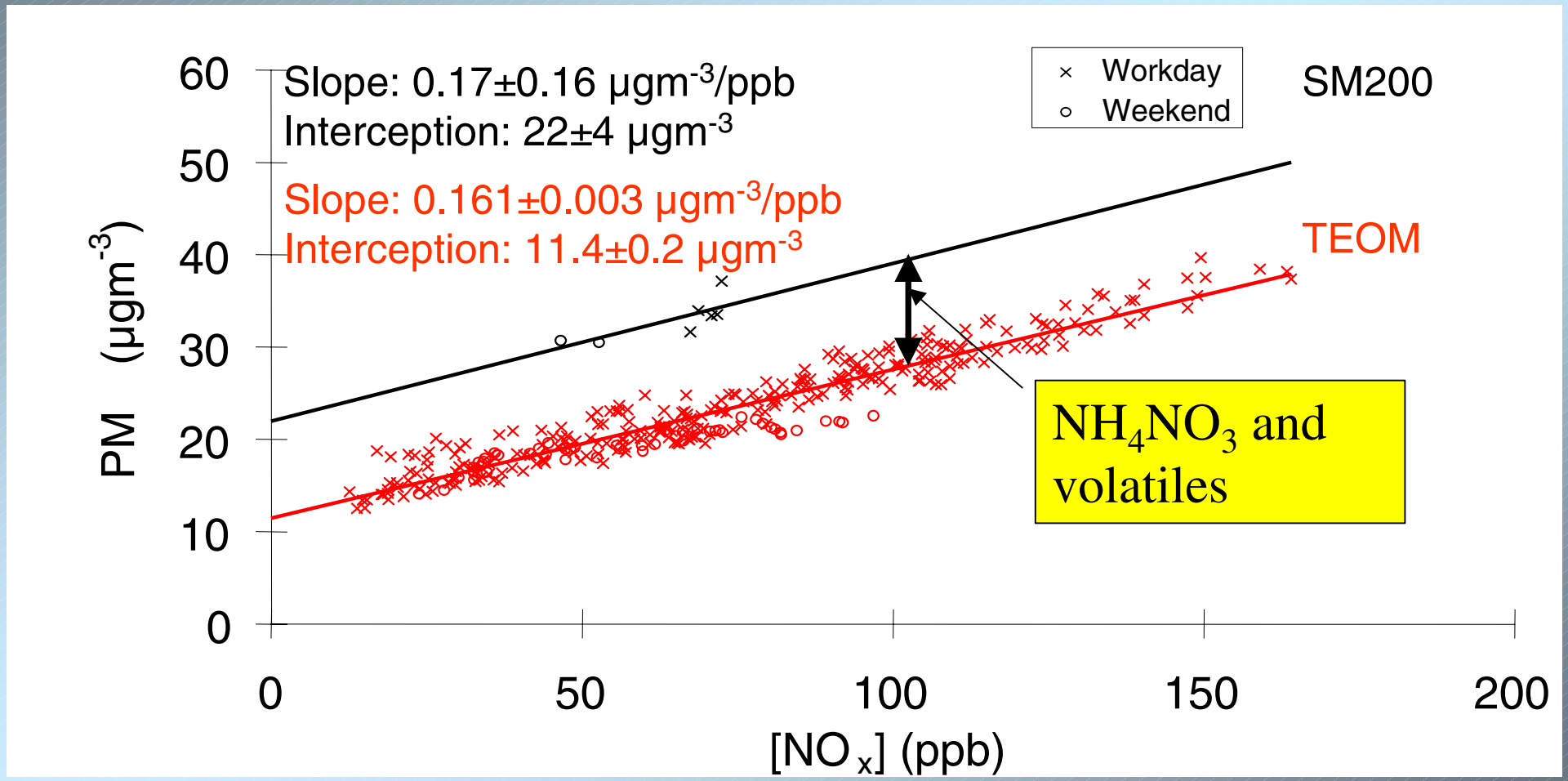
- The population exposure with PM_{10} can only be reduced with a small fraction by particle filters on all HDV in Denmark (22-33 fewer premature deaths)
- 20-30% (number) of the exposure with UF particles can be removed (400-800 fewer premature deaths)

- ***Parts of the population living or working close to traffic are exposed much more. Others are exposed short-time at high level, e.g. during transport. Is it dangerous?***

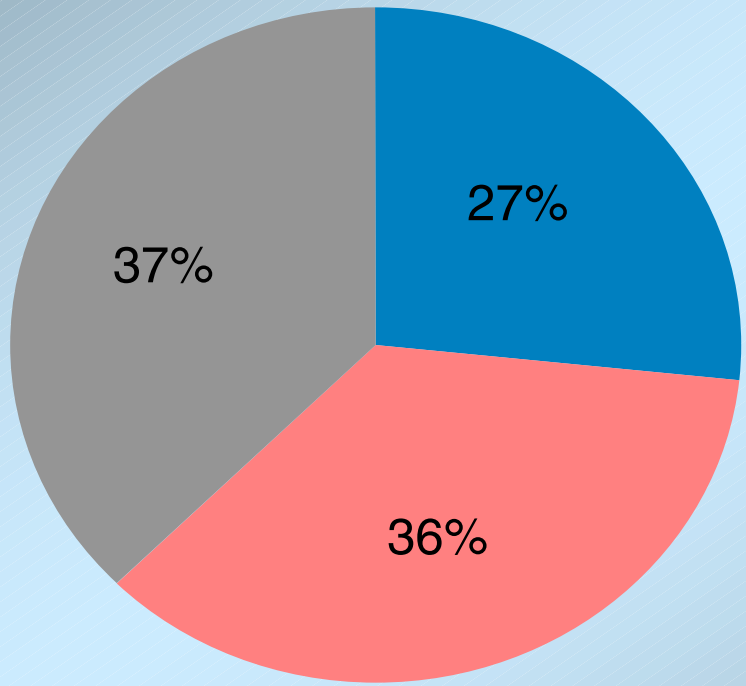
Average PM-data for a busy street sorted after time of week



Average PM-data for a busy street sorted after time of week



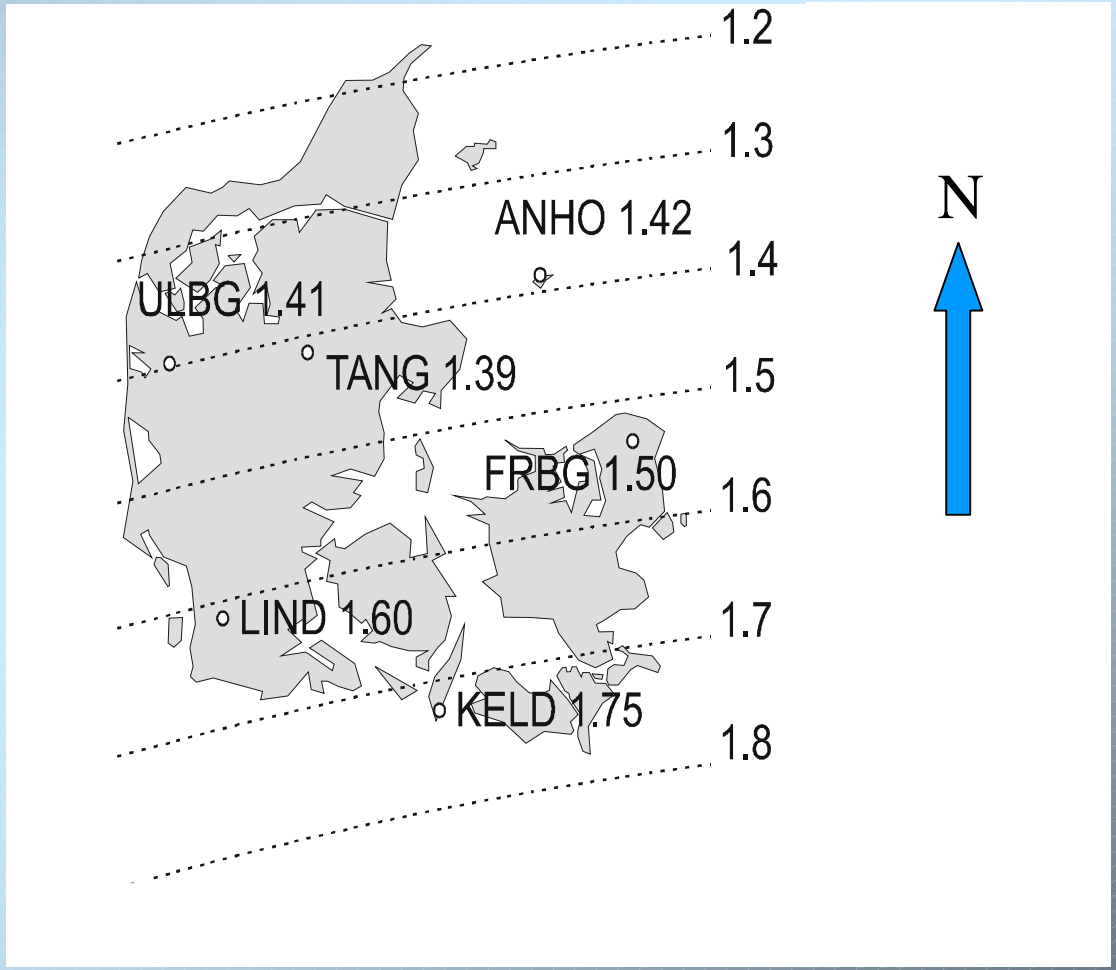
Regional particles



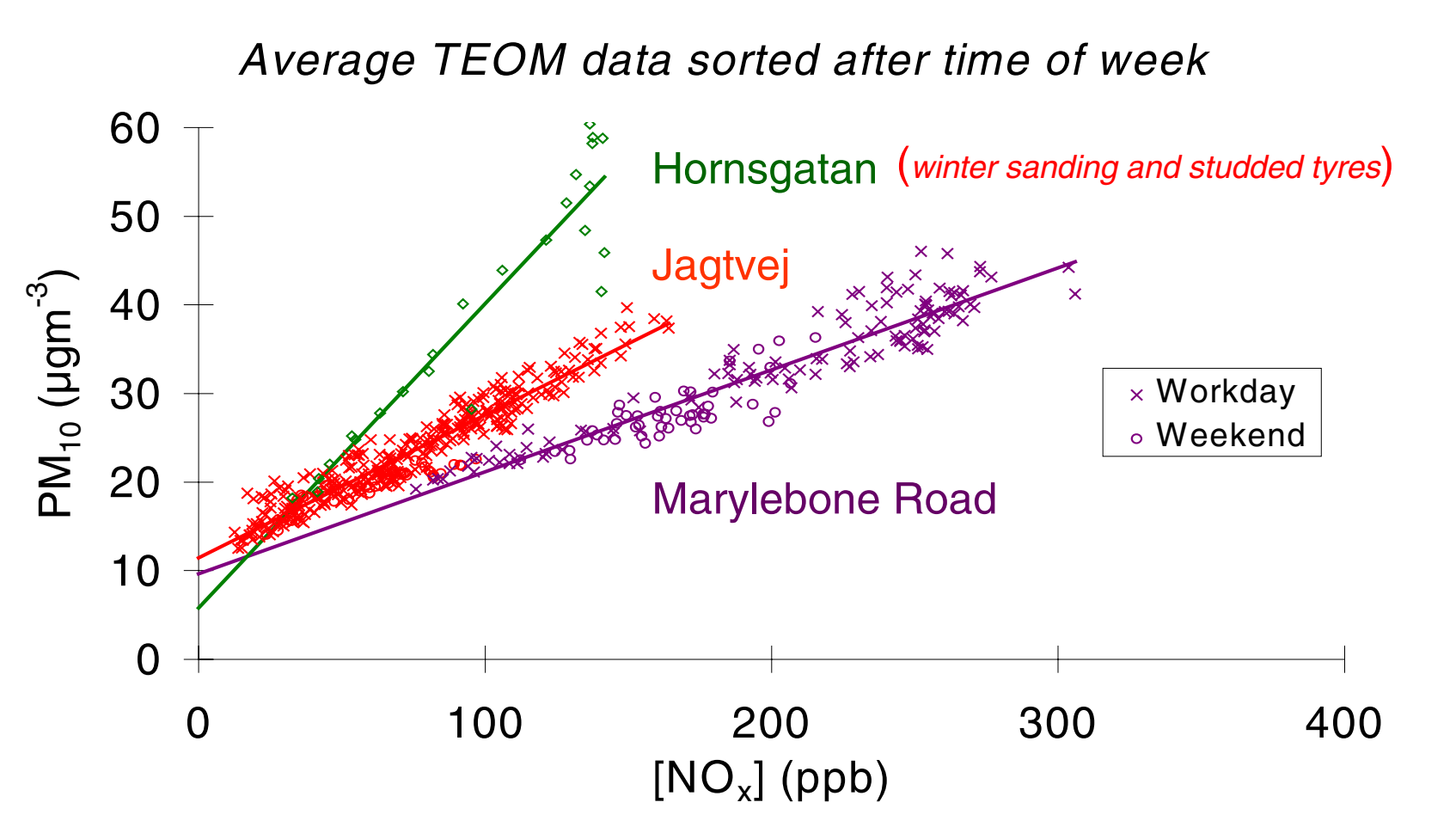
Composition of long range transported particles to Denmark

Particulate sulphur ($\mu gS/m^3$)

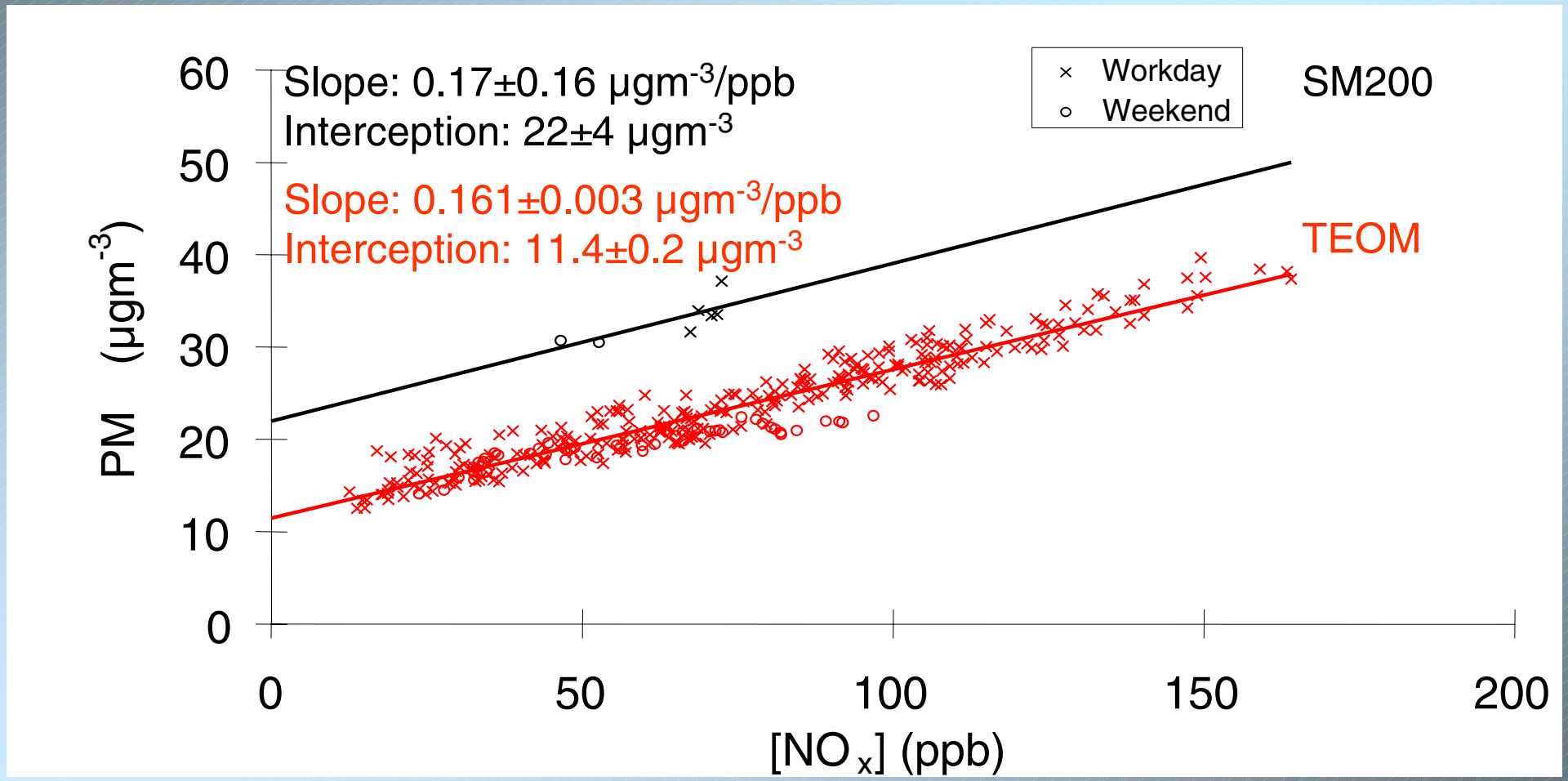
Mainly due to long range transport to Denmark



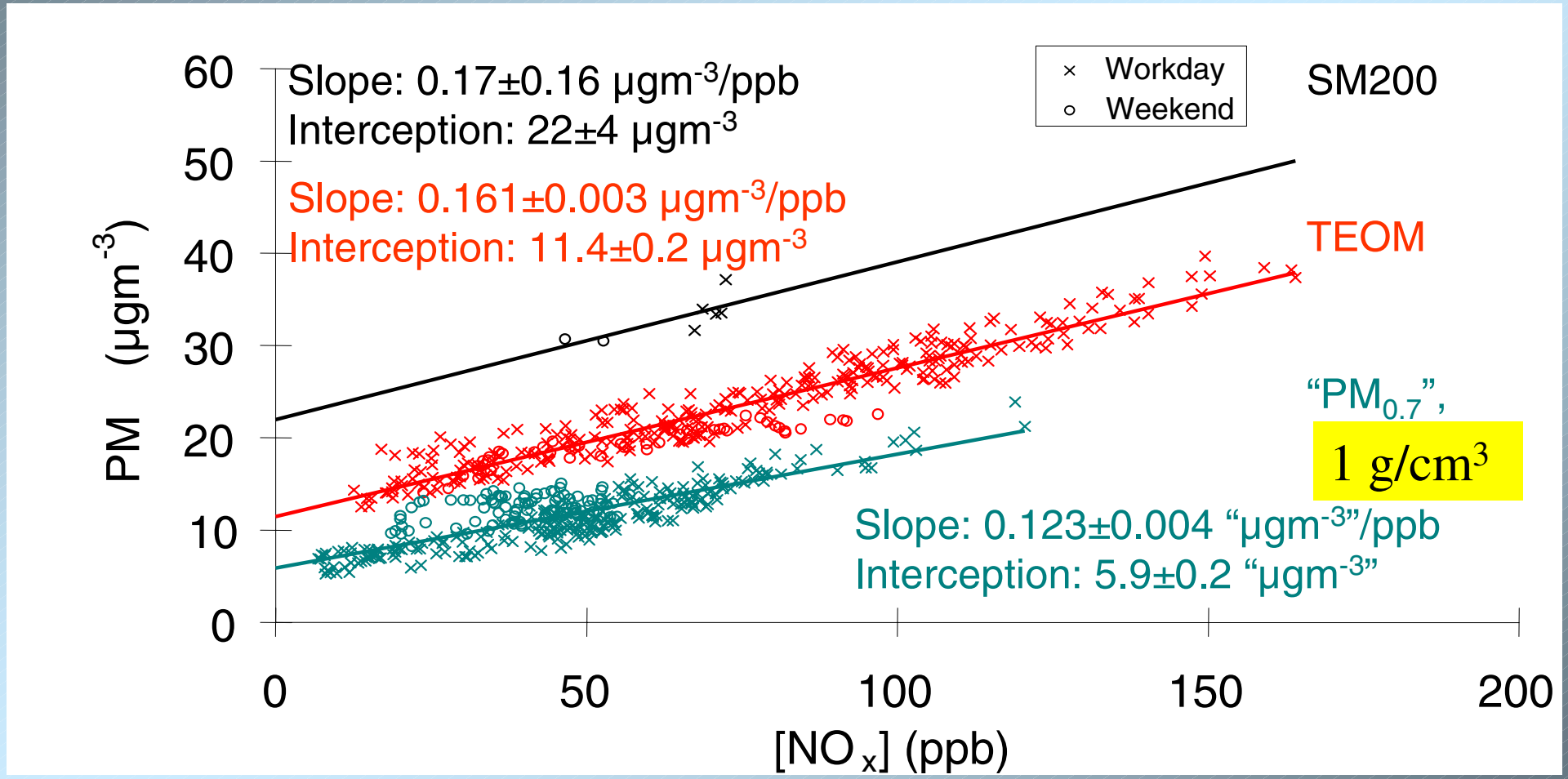
TEOM-data from Copenhagen, Stockholm and London



Average PM-data for a busy street sorted after time of week

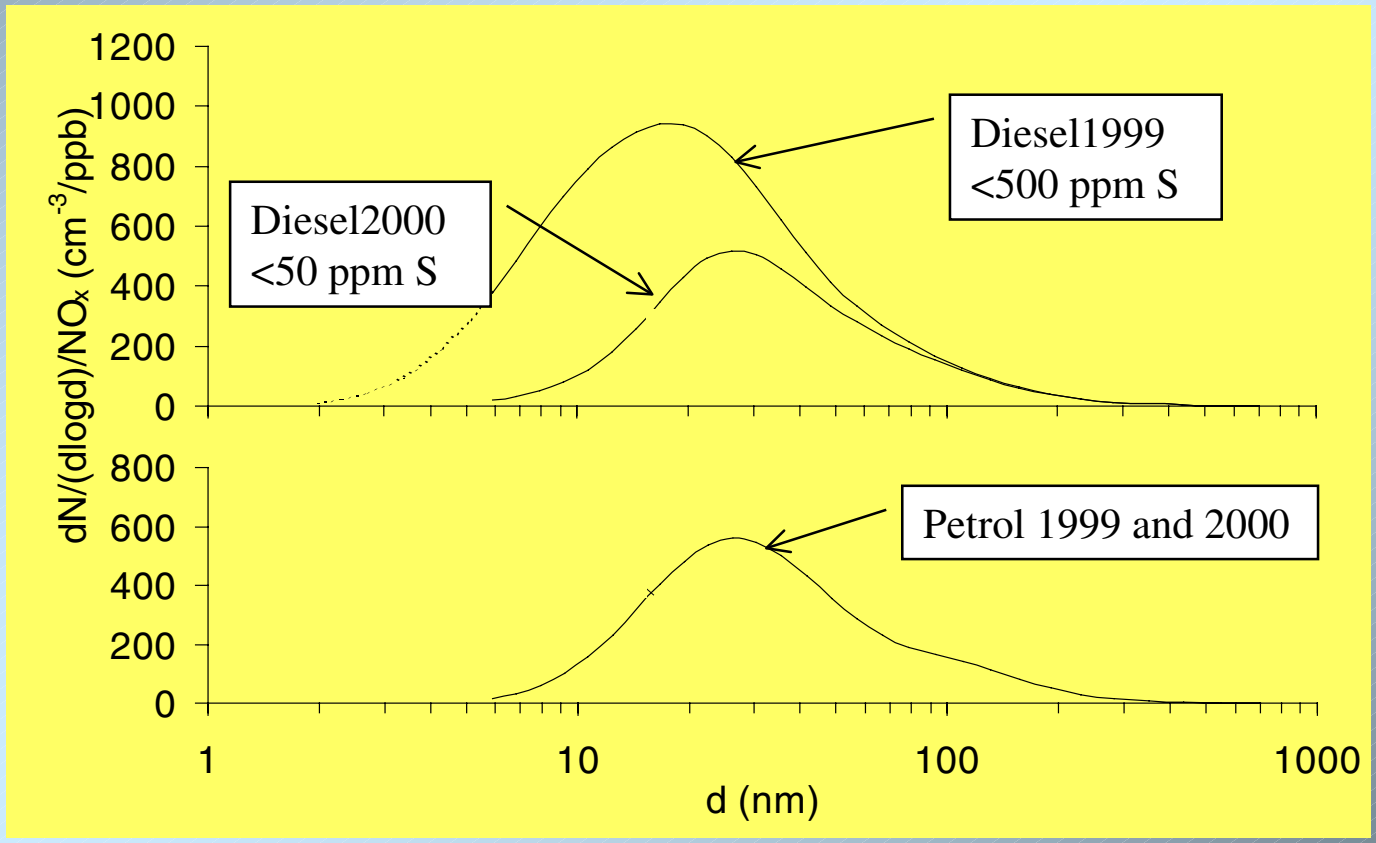


Average PM-data for a busy street sorted after time of week

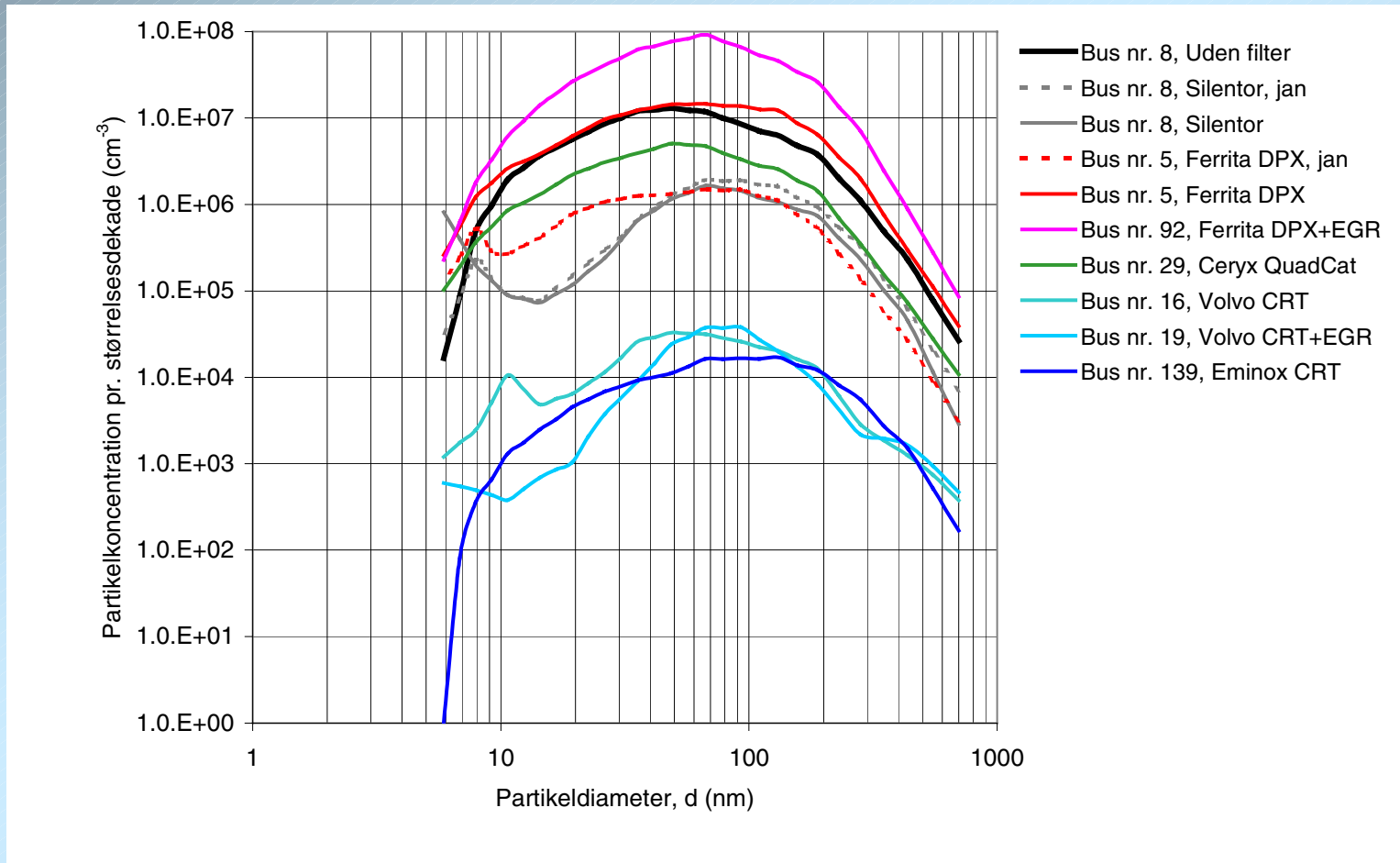


Reduced sulphur in diesel (*winter periods*)

(Peter Wåhlin et al. 2001)



Filter efficiency



Conclusions

- The effect of particle filters on exposure of people living/working close to traffic and short-time exposure is significant.
- Lack of data for epidemiological studies of UF particles (their physical and chemical properties), monitoring of relevant parameters is needed.
- Which types of particles do we want to remove? The measures are different!