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Apportionment of the road traffic contribution to PM10 and PM2.5 in Switzerland

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The main objectives of this project are the identification of the major sources of ambient particulate matter (PM10 and PM2.5), and the quantification of the contributions of these sources at different locations in Switzerland. The project is especially focused on vehicular emissions, as road traffic is known to be an important source of particulates. Our work is supposed to yield helpful informations in order to develop strategies for the reduction of ambient fine particle concentrations. This project was started in August 1997 and will continue until July 2000.

Background:

Several recent epidemiologic studies show a correlation between the concentration of ambient particulate matter and adverse health effects. It was found, that the mass concentration of particles with aerodynamic diameters less than 10μm (PM10) represents a good measure for health hazards resulting from particulate air pollution. Particles of this size range remain suspended in air for long time periods and are small enough to penetrate into the respiratory tract. Suspended particles produced by anthropogenic activities are typically smaller than 2.5μm in diameter (fine particles). In contrast, particles of natural origin are mainly in the size range between 2.5 μm and 10μm (coarse particles).

There is little information on how suspended particles cause harm to human health. However, it is suspected, that fine particles might be more likely to contribute to adverse health effects than coarse particles. Fine particle mass concentrations are typically denoted as PM2.5 (in analogy to the definition of PM10).

From March 1998, new ambient air quality standards for particulate matter (PM10) are in force in Switzerland. An annual standard of 20μg/m^3 (arithmetic mean) and a daily standard of 50μg/m^3 (not to be exceeded more than once a year) were established.

The measurements within the Swiss National Air Pollution Monitoring Network (NABEL) shows, that violations of the new standards occurs at urban, suburban and also at rural locations. In order to develop reduction strategies, a quantitative understanding of source contributions to ambient PM10 levels is required.

What are the main sources of PM10 and PM2.5 ?

Particles resulting from human activities as well as particles of natural origin are contributing to ambient particulate levels (PM10 und PM2.5). The most important sources are:

natural sources:
marine aerosol
windblown soil dust
biogenic aerosol (spores, pollen, plant fragments, ...)

anthropogenic sources:
emissions of road traffic
emissions of off-road vehicles/machines (construction/agricultural machines, airplanes, railways, ships,...)
stationary combustion processes (coal-, oil-, and wood combustion, waste incineration,...)
industrial processes (steel mills, smelters,...)
combustion of agricultural waste

A significant fraction of the ambient particle mass concentration belongs to material which results from the conversion of gaseous species by atmospheric reactions (secondary aerosol). The sources of precursor gases for secondary aerosol are anthropogenic as well as of natural origin.

In order to determine the contribution of road traffic to the ambient PM10 and PM2.5 levels, the following traffic related particulate emissions must be distinguished:

primary emissions (directly emitted particles from incomplete combustion)
emissions of tire and brake debris, resuspension of road dust
contribution to the secondary aerosol

Concept of this study:

Source identification and quantitative determination of source impacts are carried out with the use of a receptor model. Additional informations are obtained by appropriate monitoring of aerosol parameters (high time resolution) and specific chemical analysis of PM10 and PM2.5 samples.

Receptor model:

A data set is generated, consisting of the concentrations of a variety of marker compounds abundant in PM10 and PM2.5 samples. The particle samples are collected on quartz fiber filters (high volume sampler) at different measuring sites of the Swiss National Air Pollution Monitoring Network (NABEL).The chemical characterization of the PM10 and PM2.5 samples includes:

- Determination of elemental and organic carbon concentrations (EC and OC) with the coulometric method.
- Determination of the concentrations of water-soluble anorganic ions (SO_4^{2-}, NO_3^-, NH_4^+, Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^-) by ion-chromatography.
- Analysis of trace elements by inductively coupled plasma mass spectrometry (ICP-MS).
- Analysis of parent PAHs and PAH Derivatives by Two-Step Laser Mass Spectrometry (L2MS), performed at the Department for Organic Chemistry at the ETH Zurich.

- Determination of the total protein concentration, performed by the Institute for Hygiene and Applied Physiology at the ETH Zurich.

Four samplings sites were selected for this study. They are differently affected by local pollution sources:

A. Urban site, located at a road with heavy traffic (NABEL measuring site Bern).
B. Urban site, located in a park (NABEL measuring site Zurich).
C. Suburban site (NABEL measuring site Basel).
D. Rural and elevated site (NABEL measuring site Chaumont).

The acquired data set is analysed by means of factor analysis. Application of this technique allows the determination of the contributions of major emission sources of particulate matter.

Chemical composition of PM10 and PM2.5:

Figure 1 shows the average chemical composition of PM10- and PM2.5 samples at the measuring site in Zurich (Jan.98 – Jun.98). In Figure 2, enrichment factors of various trace elements (PM10 samples from the four measuring sites, Jan.98 – Jun.98) are illustrated. High enrichment factors (> 5) indicates, that the element concentration is influenced by emission sources other than natural (mineral soil dust).

Particle monitoring with high time resolution:

Beside the receptor modelling study, informations on particle emissions of road traffic will be obtained by particle monitoring measurements.
For example, a measuring campaign was conducted at the NABEL site Haerkingen (04.02.-20.05.98). This measuring site is situated about 30m north of a highway (50'000 to 60'000 vehicles per day). Depending on the wind direction, the site is either influenced by local road traffic emissions (winds from south), or it is not directly influenced by local emission sources and therefore represents air pollution levels which are typical for the swiss plateau (winds from north to north-east). Different particle parameters (especially PM10) were measured with high time resolution (10min), and concentrations of gaseous pollutants (NO_x, NO, CO) as well as meteorological parameters were recorded. In addition, an automatic loop detector was used to measure the traffic density of the nearby highway.
Figure 3 shows wind roses for NOx, black carbon (BC) and PM10, as well as the distribution of the prevailing wind directions (air pollutants and wind direction were recorded with a 10 min time resolution). From this kind of measurements, the contribution of the local road traffic to the ambient PM10 level can be estimated. On sundays, heavy duty vehicles are banned from highways in Switzerland. It is therefore possible to determine the contributions associated with particulate emissions of passenger cars and duty vehicles, respectively.

During this project, more field campaings will be conducted. We are planning to perform measurements at two urban measuring sites simultaneously. Both measuring sites are within a close distance, but differently affected by local sources. One site is at a roadside with heavy traffic, the other site is located in a park and might be considered as representative for the ambient particle level of the 'urban background'. By comparison of the measurements at both sites, it should also be possible to obtain information on the contribution of local road traffic to the ambient PM10 level.

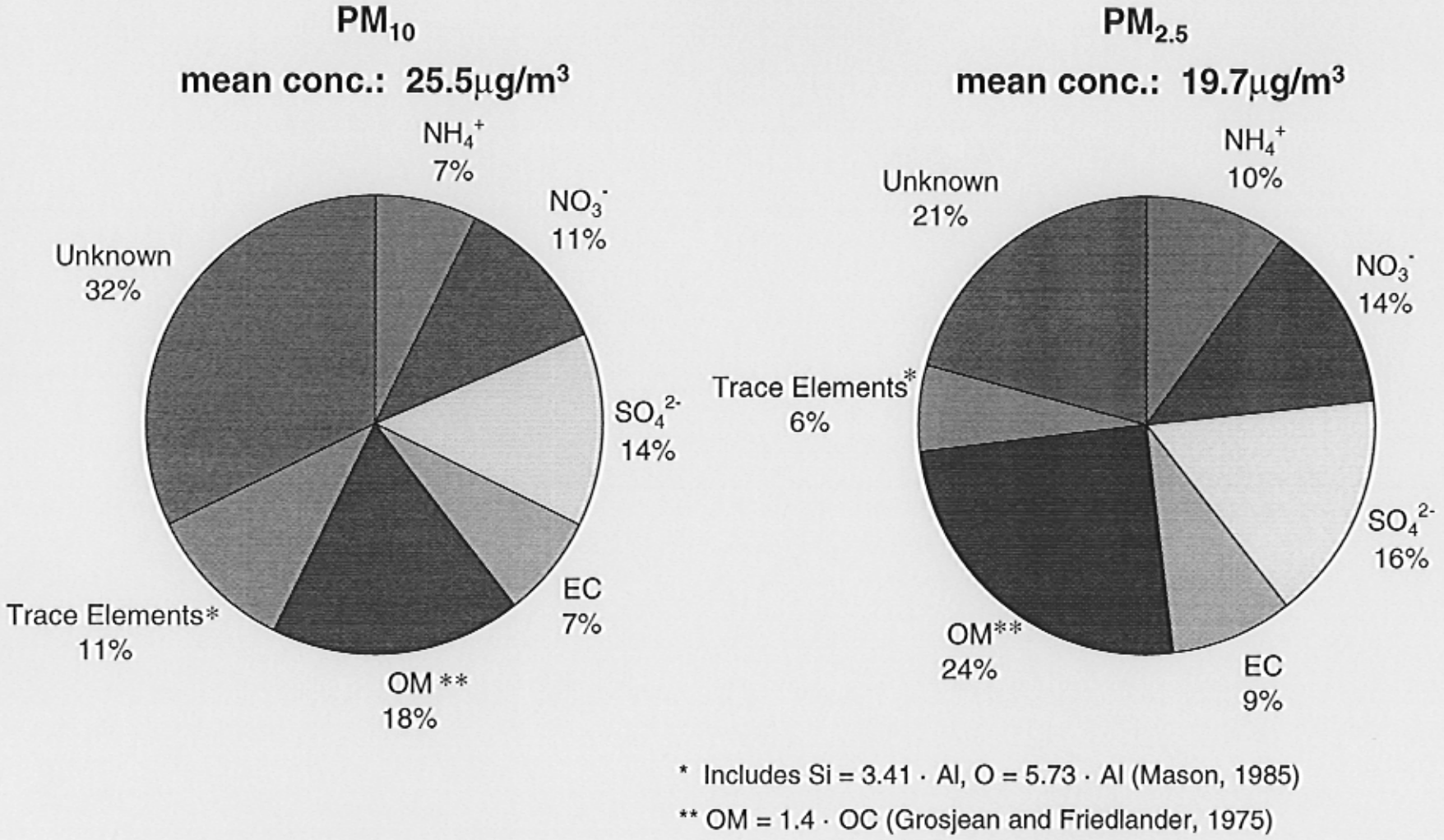

Fig. 1: Average Chemical Composition of PM_{10} - and $PM_{2.5}$ Samples at Zurich (Jan.-Jun.98)

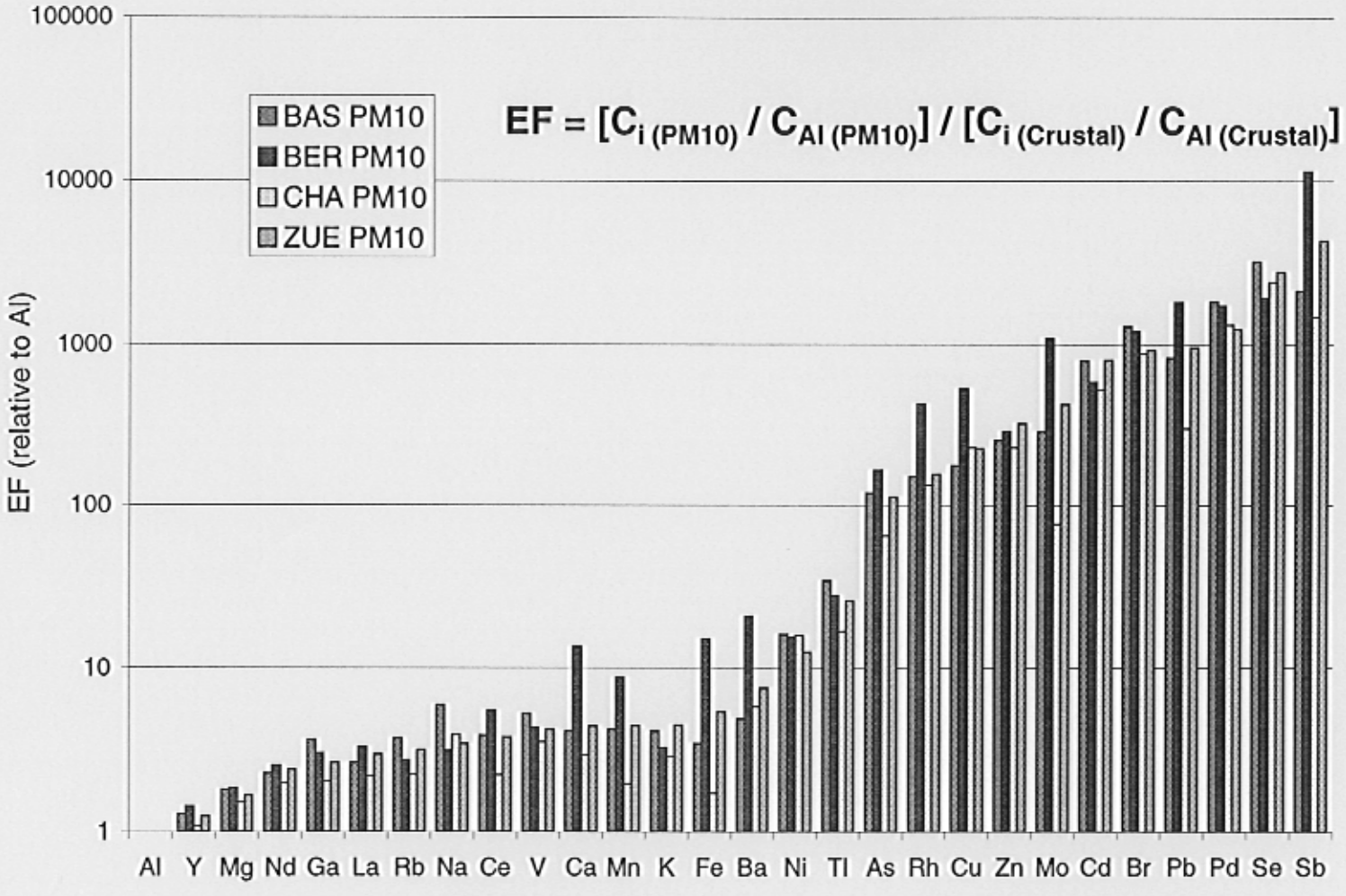

Fig. 2: Enrichment Factors Based on Crustal Concentrations (Relative to Al)

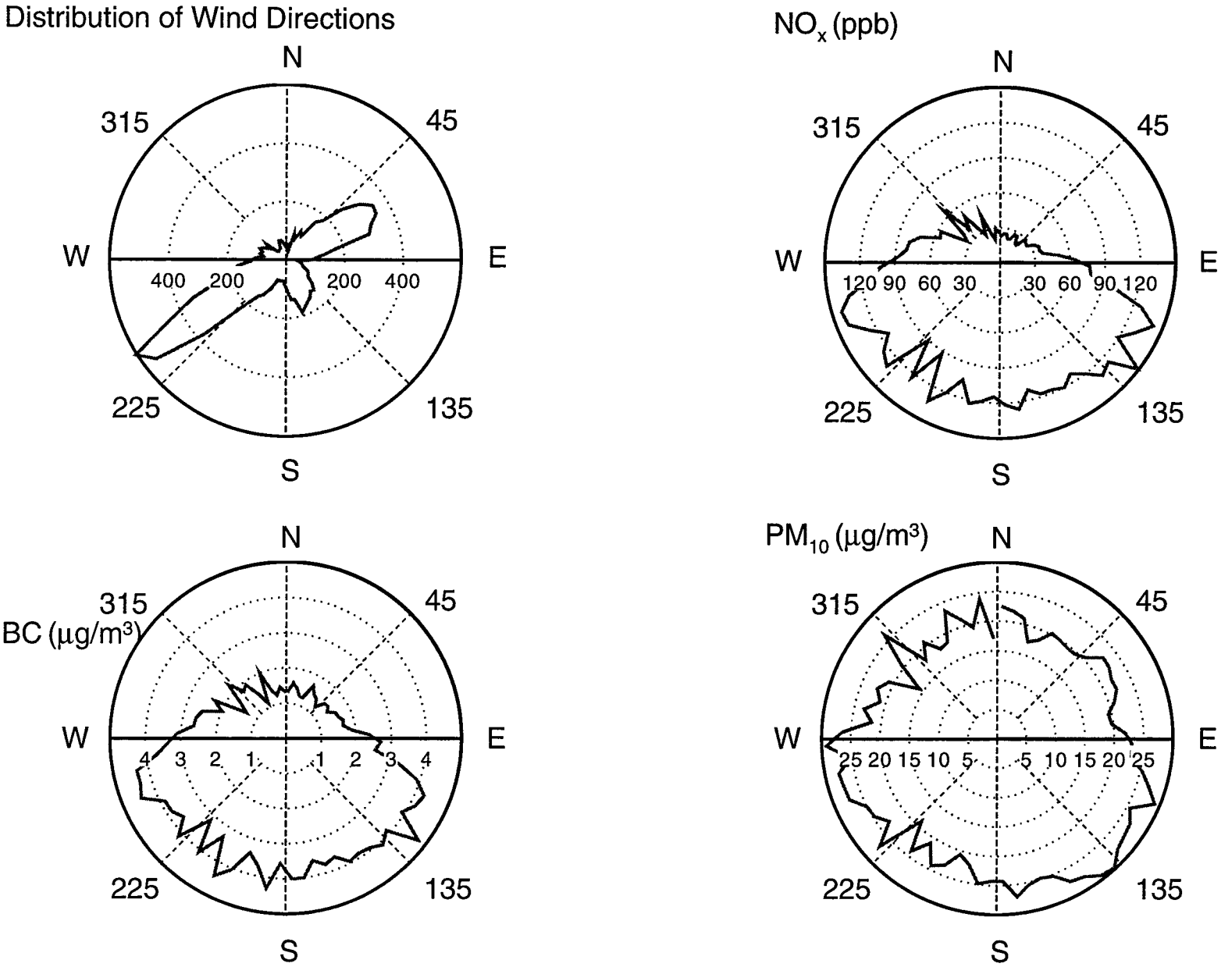

Fig. 3: Wind Roses of Wind Directions, NO_x, BC, and PM_{10} at Haerkingen

(0.5m/s < Wind Speed < 2.0m/s, 24.02.-20.05.98)