Fact Sheet for the Determination of Dust Origin Using SEM-EDX Single Particle Analysis on Sigma-2 Samples

PM Immission?   Passive Sampling on Boron Substrate   SEM-EDX Single Particle Analysis   Morpho-Chemical Classification with ML   Monitoring   Determination of Origin

?   ①   ②   ③   ④

Applications

Monitoring and determination of the origin of the airborne coarse-mode of dust (PM10-2.5). This size fraction is important, since the majority of both abrasion particles from road and rail traffic and mineral dust from construction work, gravel pits or quarries is present in this fraction.
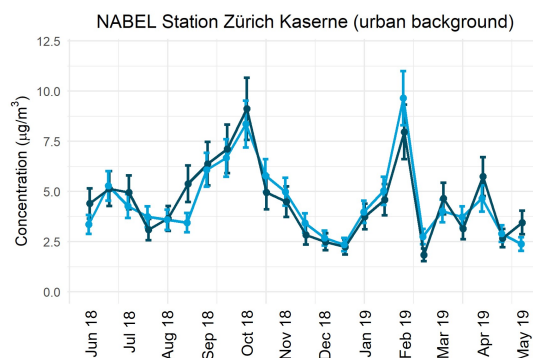
Description of the measurement technique

Samples are collected by means of a passive sampler ① (Sigma-2, according to VDI 2119, 2013) on a boron surface (magnified in ①). A statistically relevant number of single particles (> 1000) of this sample is subsequently imaged and measured individually, by means of a scanning electron microscope ② (SEM), which is equipped with an energy-dispersive x-ray spectroscopy (EDX) detector for the characterisation of the elemental composition. The large multidimensional data set is processed using a specifically developed particle classifier ③ that uses machine learning. Hereby the temporal evolution of the dust concentration and the proportions of the different sources can be ascertained ④.

Accuracy of the measurement?

The deviation of the PM10-2.5 annual mean value stemming from the SEM-EDX single particle analysis amounts to 0.90 % with respect to the reference method (gravimetry). The concordance correlation coefficient r_{ccc} is 0.90, which indicates that the measured data are almost completely concordant. Furthermore, the Bland-Altmann statistics provide a bias of $+ 0.04$ $\mu g/m^3$ for the single particle analysis and the corresponding 95% confidence intervals are ± 1.61 $\mu g/m^3$. This translates to 95 % of future SEM-EDX single particle measurements being located within this range of concentrations as compared to gravimetry.[a]

[a]The above parameters are to be understood as site-related. Greater deviations are to be expected for an urban traffic location.

Comparison of PM10-2.5 measurements over a whole year (26 periods of 16 days each) at an urban background site. The light blue measurement series corresponds to the gravimetric analysis (PM10-PM2.5) and the dark blue to the SEM-EDX single particle analysis. The latter is NaCl-corrected, meaning that it does not take into account any of these salt particles. Gravimetry data source: NABEL measuring network - Project: Characterization and determination of the origin of coarse dust particles in PM10, 2018-2019. Last updated: 10.02.2020

What particle classes?

The morpho-chemical particle classifier was trained with over 100'000 particles from different locations and distinguishes between the following 5 classes. Metallic particles, tire abrasion particles, minerals, biogenic-organic particles and salt particles. These have further subgroups, which are mainly based on morphological criteria (e.g. metallic spheres).

Advantages of this measurement technique?

The Sigma-2 is easy to install and the sampling is done without power, so it can be carried out in remote and difficult to access locations. Thanks to passive sampling, the duration of sample exposure can be up to 4 weeks, allowing for cost-effective and source-differentiated monitoring. Since the particles are measured individually and divided into classes, it can be assessed, for example, whether a particular chemical element is contributed by only a single particle class or by several thereof. The efficient processing of the data sets by means of a particle classifier also allows for a more direct and accurate determination of the origin of the airborne dust compared to bulk techniques. If necessary, this simplifies the adoption of targeted countermeasures.