Ultrafine Particle Concentration at a Tunnel Construction Site

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In this study the ultrafine particle concentration at a tunnel construction site was investigated using different methods. The particle number concentrations and the size distributions were determined with using two SMPS (Model 3034, 3936 both TSI) and an electrical diffusion battery (EDB200, Matter Engineering). In addition, detailed investigations of single particles were carried out using an analytical transmission electron microscope (TEM). To collect the particles directly on TEM grids, an electrostatic sampler was used.

Figure 2 shows the experimental setup and the schematic layout of the tunnel construction site. The yellow arrows indicate were the tunnel is built by blasting. At this tunnel construction site, no tunnel boring machine was operated and the tunnel in exclusively built by blasting. At site 1 and 2 the two SMPS, the EDB and the electrostatic sampler were operated in parallel. At site 3, were measurements were performed directly in the blasting cloud, only the electrostatic sampler (battery operated) was used to collect the particles resulting from blasting.

The comparison between resulted from the SMPS and the EDB revealed a very good agreement between the three measurement devices (Figure 3, left hand side). However, the number concentrations recorded with the EDB200 were always about 30% higher than the corresponding values from the two SMPS. This constant shift indicates that there were some calibration problems with the EDB200. Also the sizes of the particles determined by the three devices are is good agreement. The EDB200 recorded slightly smaller diameters, but again, it is likely that this shift is caused by calibrations problems.

The accumulation mode particles (around 100 nm) sampled at site 1 consisted almost entirely of diesel soot as can be seen on figure 4 (right hand side). However, besides the accumulation mode particles, also nucleation mode particles (20 nm) were detected, both in SMPS scans and also in the TEM analysis. Figure 4 (right hand side) shows a TEM bright field image of the nucleation mode particles (circled in red). These particles can be seen at a higher magnification in figure 6. Based on the TEM image it can be concluded that the particles consist of two different phases: a dark (almost black) phase of only a few nm in diameter and a light grey phase of about 20 nm in diameter. The strong contrast observed in the TEM indicated that this dark phase is composed of heavy elements.

Analyses of single particles sampled directly from the blasting cloud using the electrostatic sampler are presented in figure 7. A particle size distribution of the aerosol is shown on the left hand side. This size distribution is derived from automated image analysis of TEM bright field images. It includes about 200 particles. The average diameter of the particle is about 130 nm and thus very similar to the diesel exhaust particles shown in figure 4. A chemical analysis of a representative particle performed in the TEM is also shown. Most important are the elements S and P which are not occurring in the granite host rock and thus can be attributed to the blasting agent. In summary it can be concluded that the size of the blasting related accumulation particles is similar to the size of the diesel soot. However, morphology and chemistry of the blasting particles differ significantly from the diesel soot and allow a clear distinction between the two sources.

At a higher magnification, nucleation mode particles were found (Figure 8). The size distribution derived from image analysis of TEM images shows that the mean particle diameter is between 20 and 30 nm. The morphology of the nucleation mode particles is very similar to the nucleation mode particles observed at site 1. A chemical analysis performed in the TEM showed that the nucleation mode particles contain significant amounts of Pb, which explains the high contrast of the dark phase. In addition, S and Cl were detected. These elements most likely are contained in the light grey phase of the nucleation particles.

The conclusions are outlined in figure 9.

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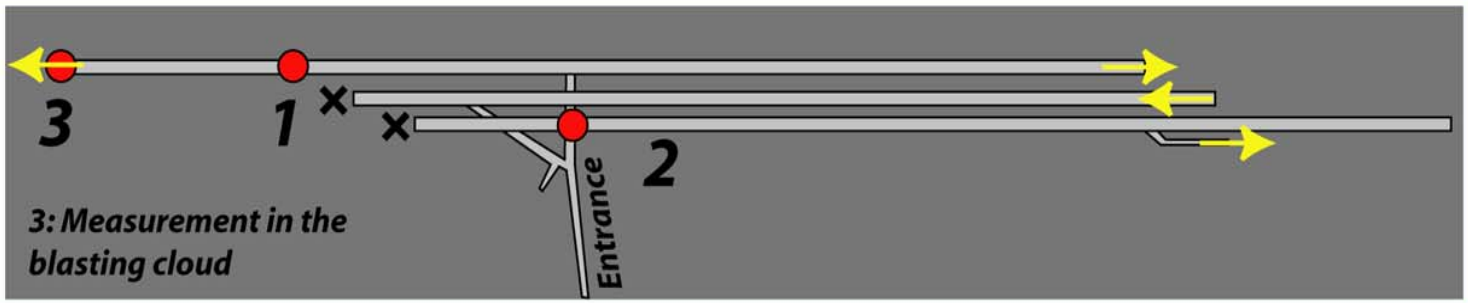
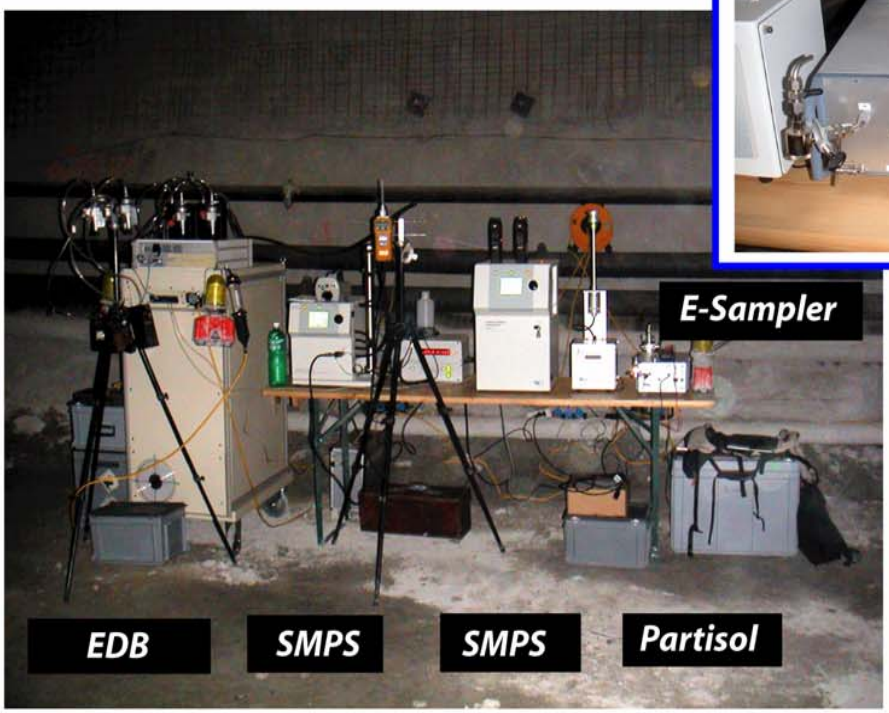
Schematic layout and experimental setup

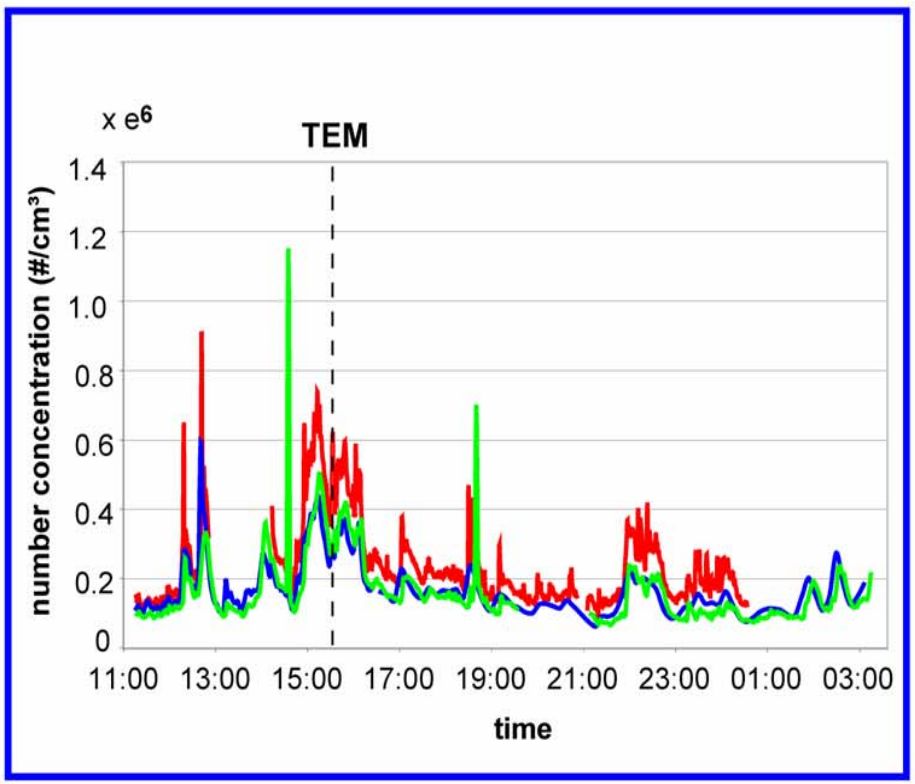


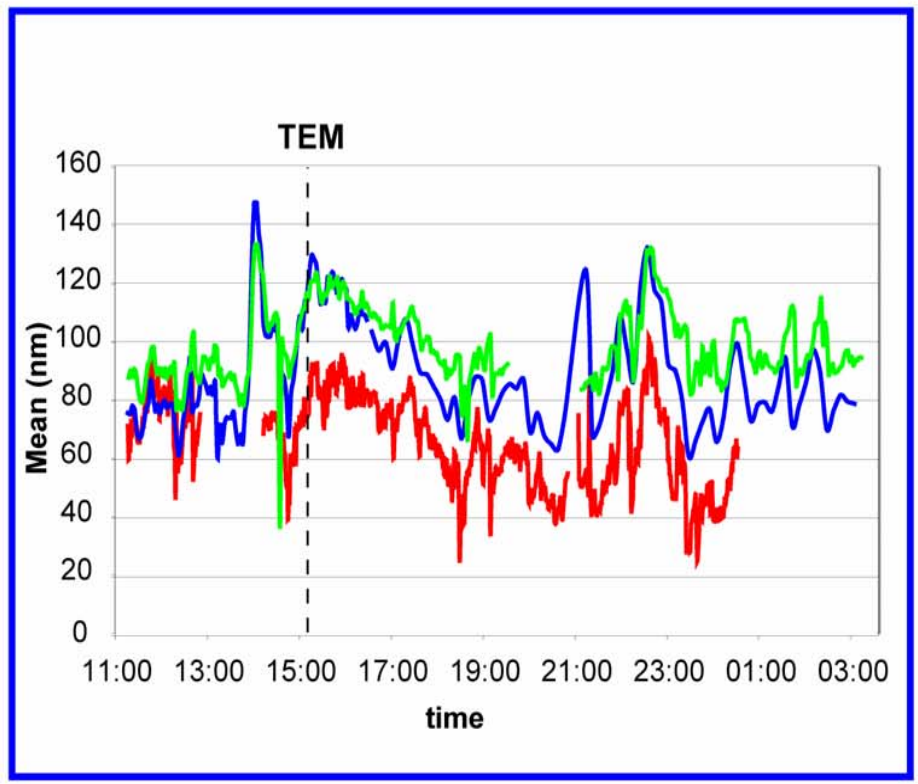
E-Sampler to collect particles for TEM analysis (10 - 500 nm)



EDB (Electrical diffusion battery) and SMPS (Scanning mobility particle sizer) to measure the particle size distributions on-line.

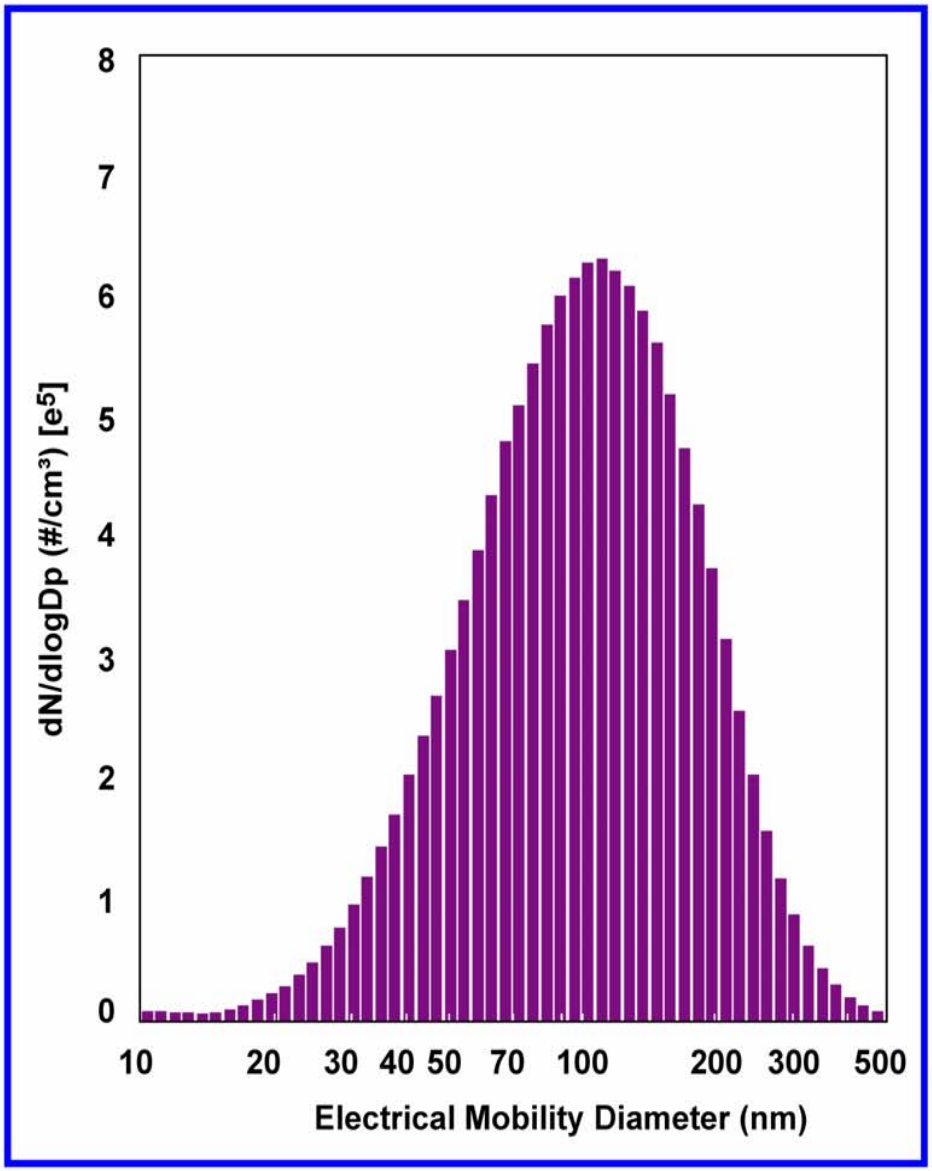
Comparison between EDB and SMPS results



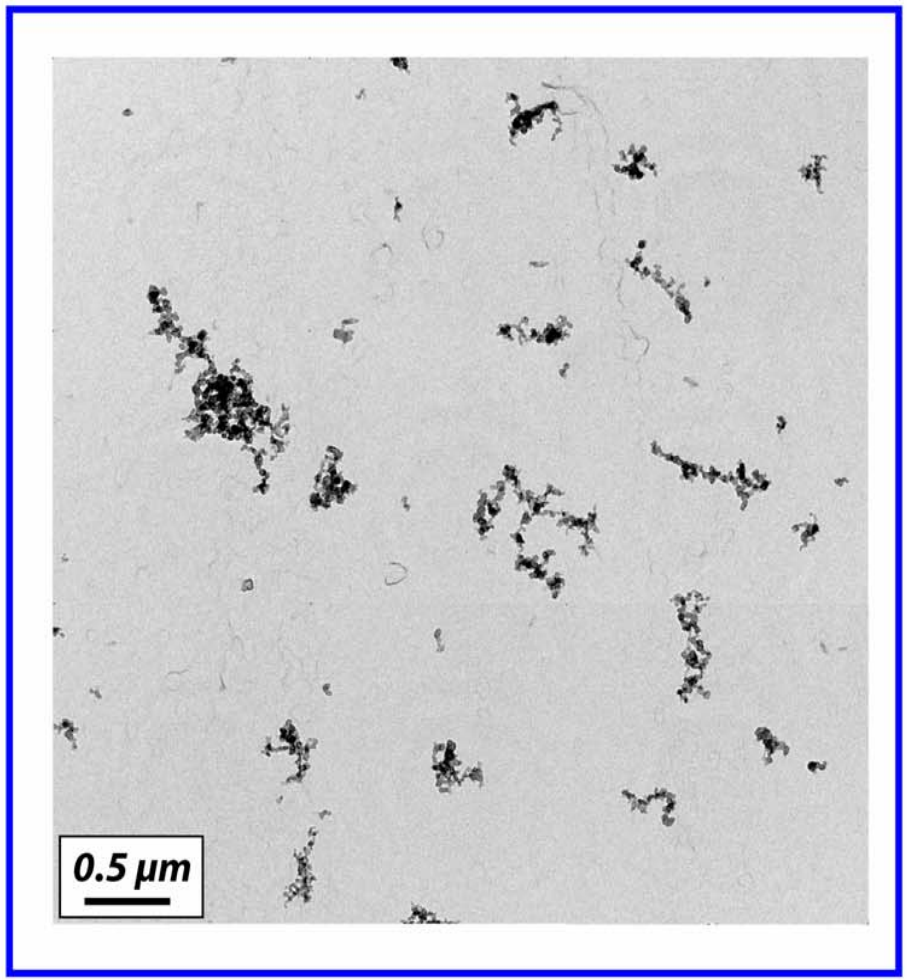


SMPS (3936L22) SMPS (3034) EDB200

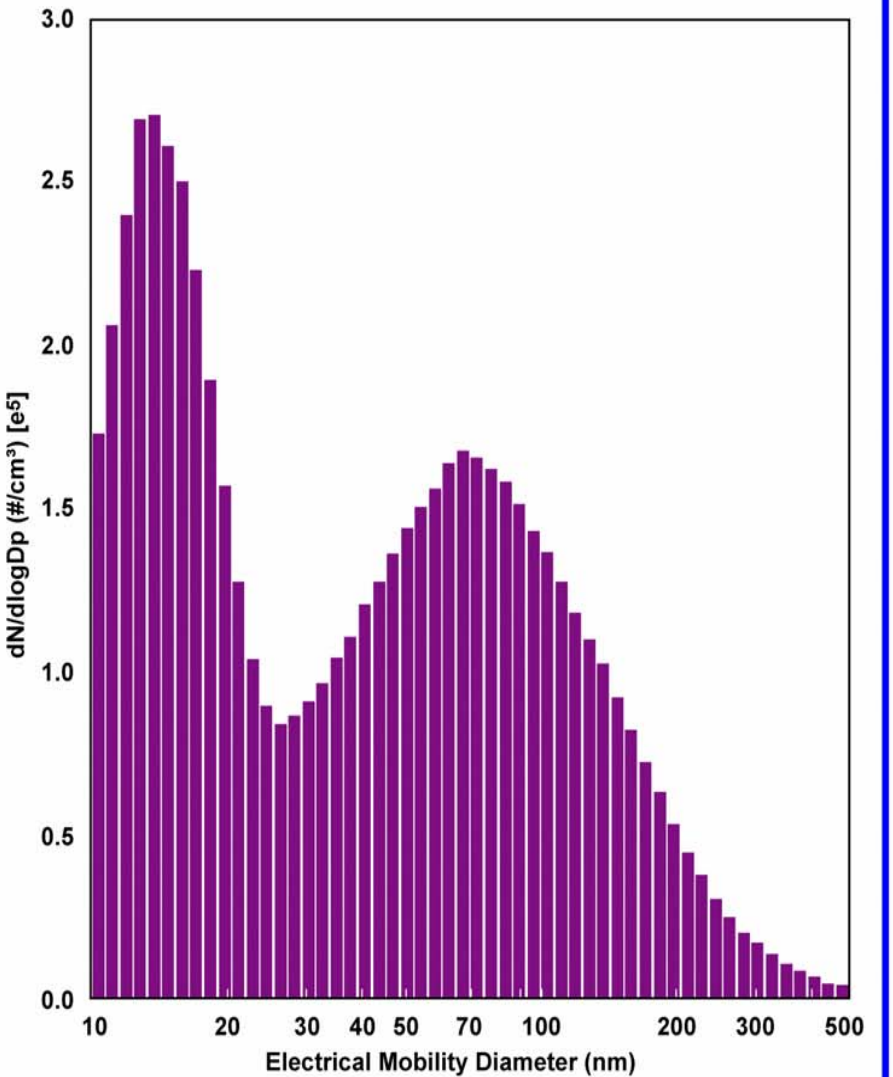
Comparison I: SMPS - TEM



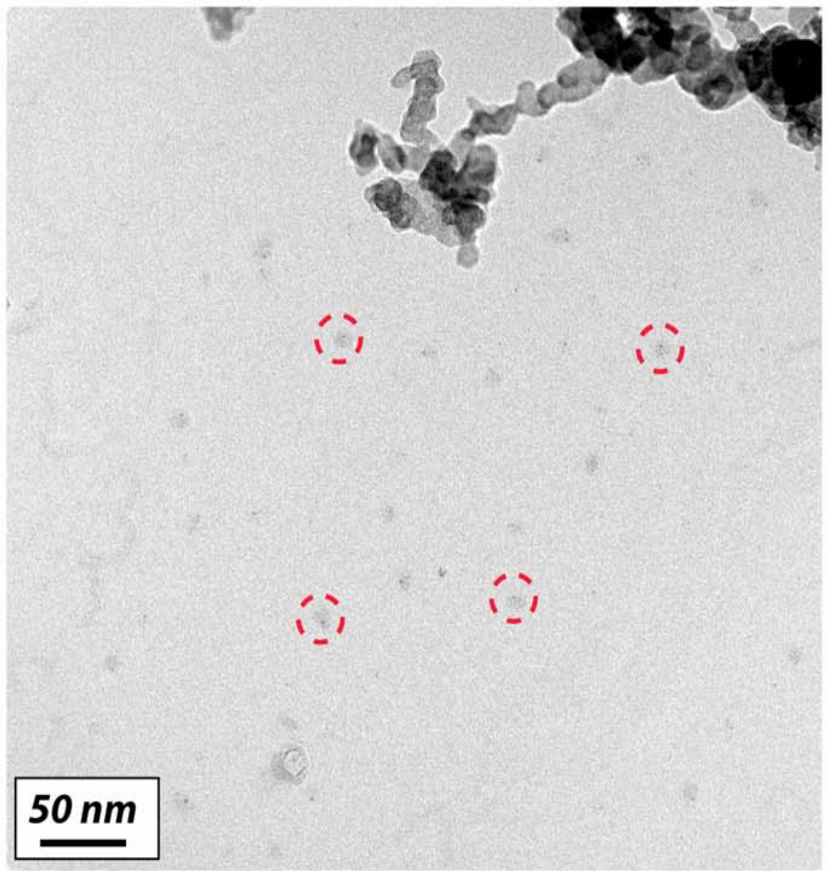
TEM bright field image



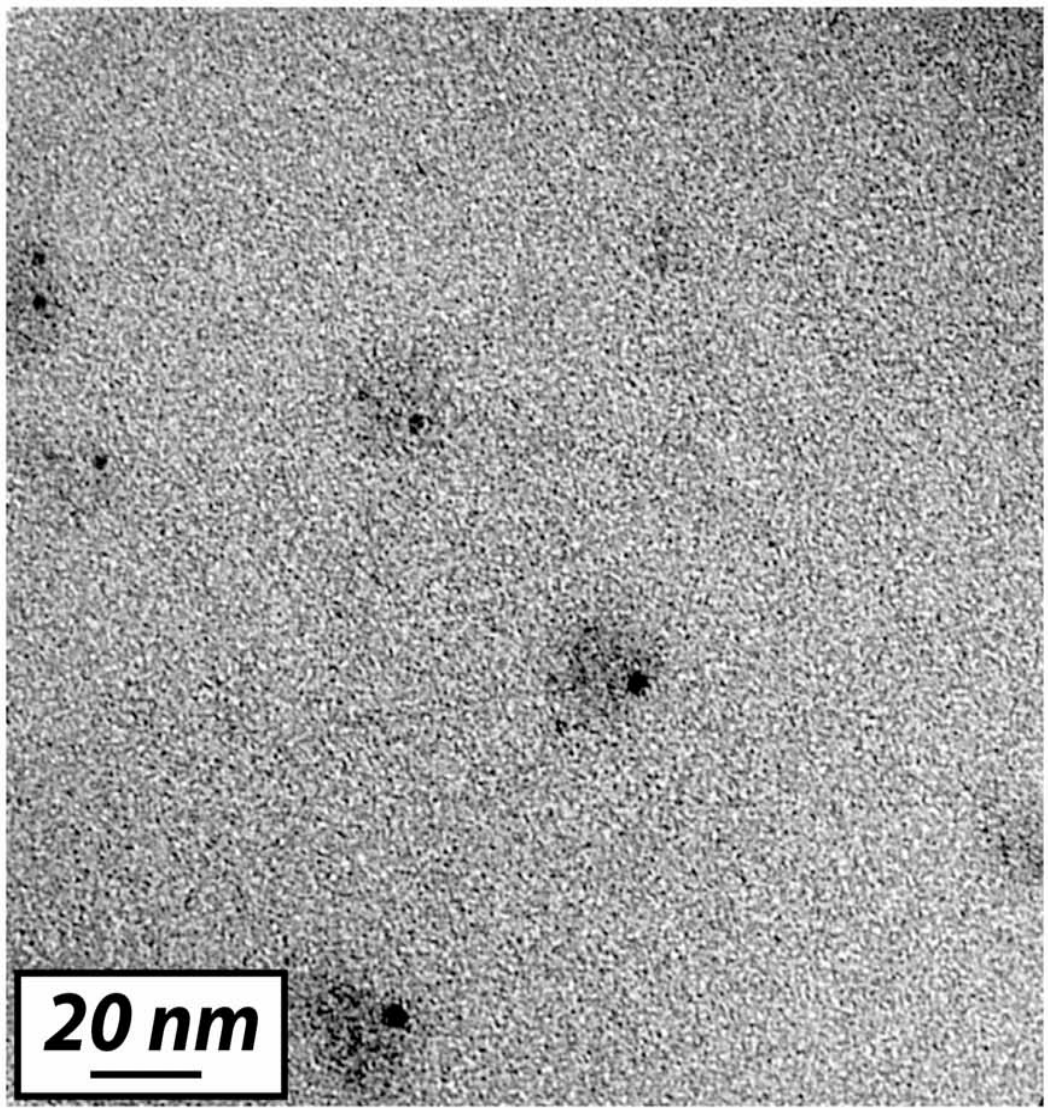
Comparison II: SMPS - TEM



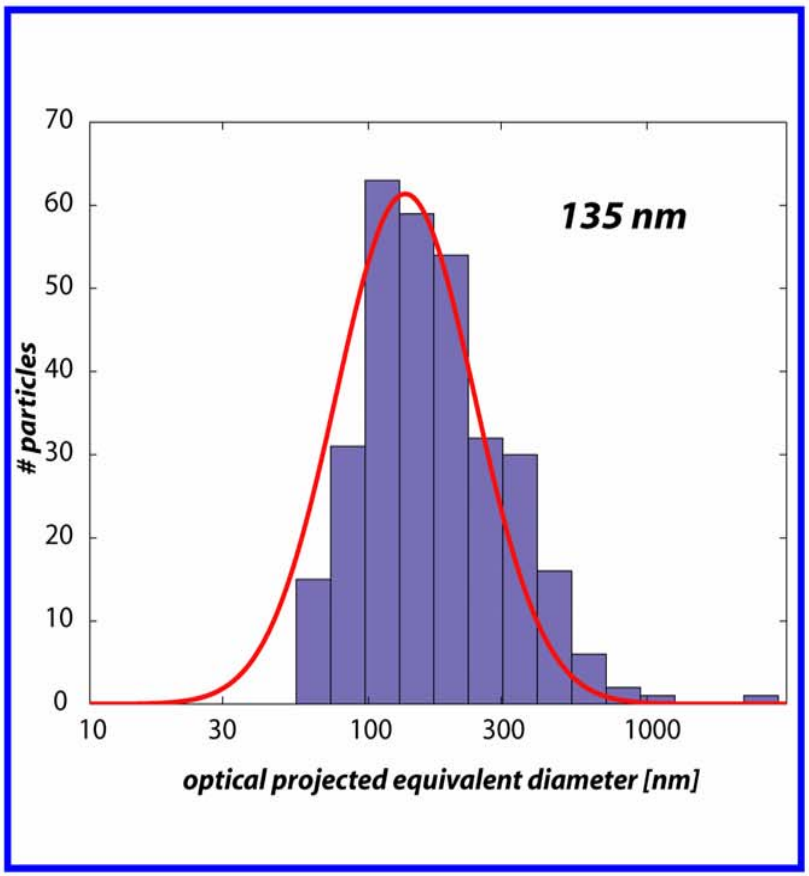
TEM bright field image



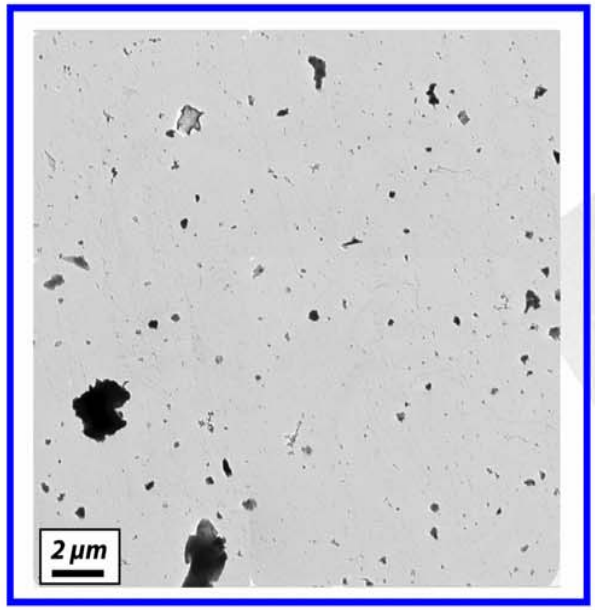
TEM bright field image



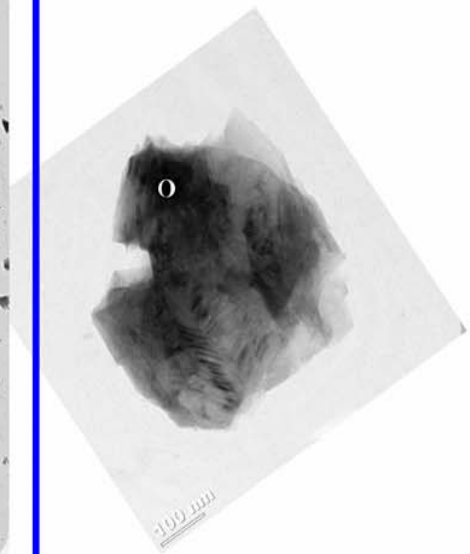
Blasting I: Accumulation Mode

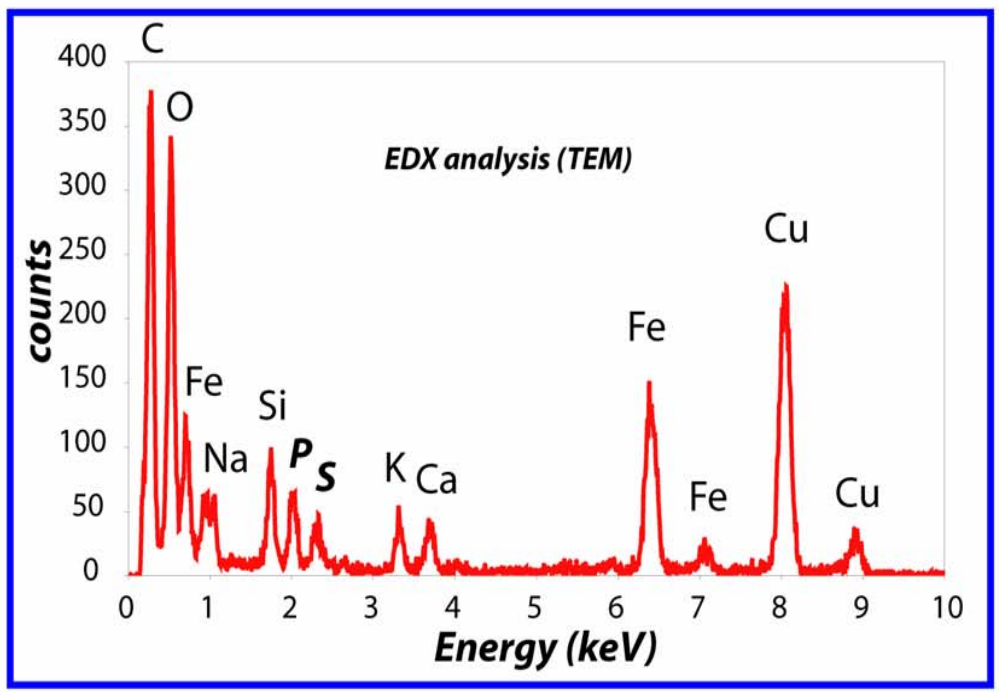


Size distribution based on TEM - Image Analysis

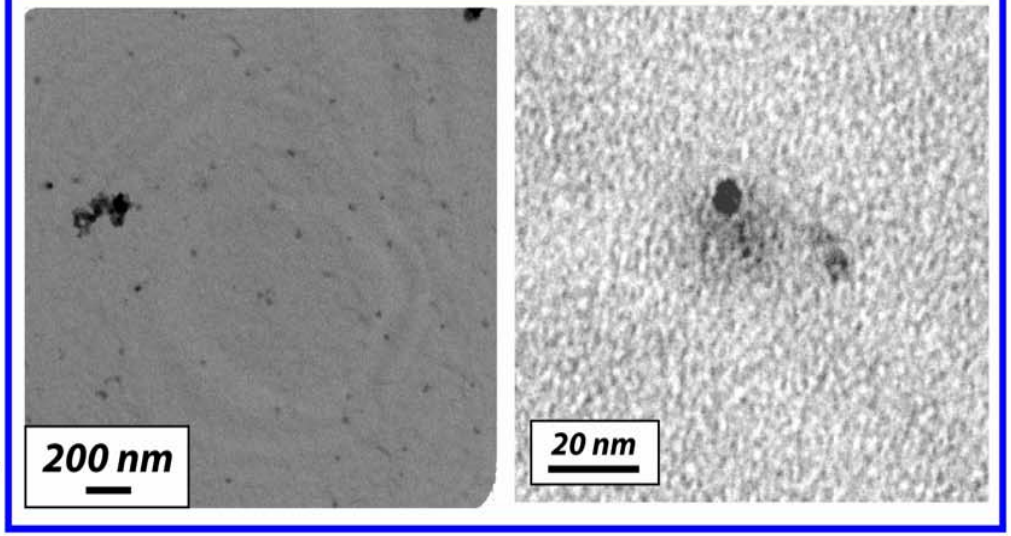


TEM bright field image

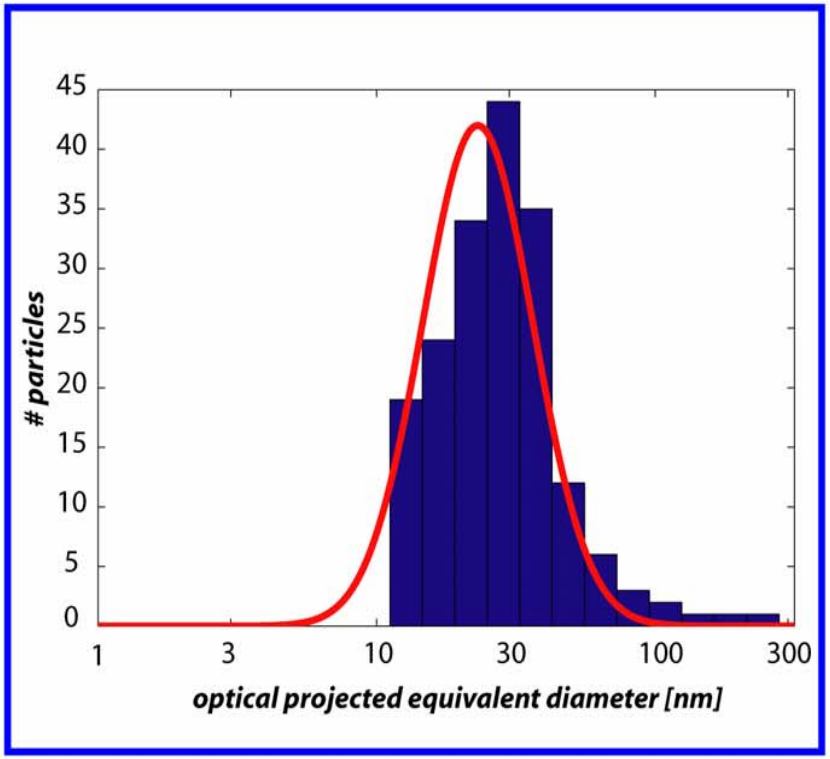




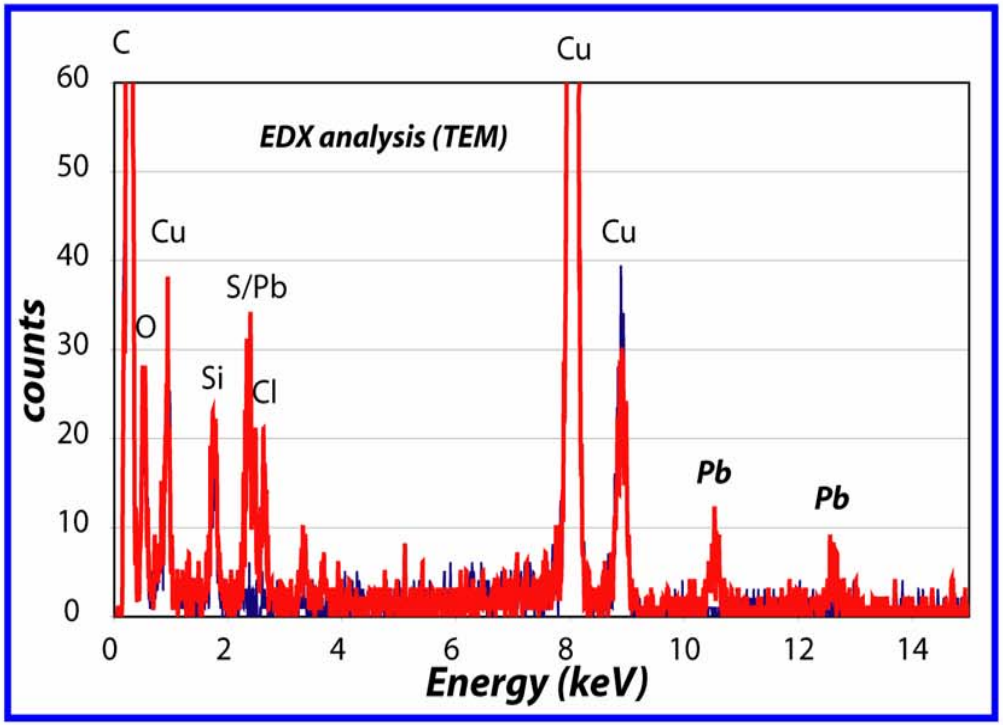
Blasting II: Nucleation Mode



TEM bright field image



Size distribution based on TEM - Image Analysis



Conclusions

Site 1 + 2	Results (number concentration and size) from the EDB and the SMPS are in good agreement.
Site 1	Accumulation mode particles are dominated by soot, particles related to blasting seem to be of minor importance. Nucleation mode particles were observed.
Site 3 (Blasting)	Accumulation mode particles (140 nm) are composed of fragmeted geological material plus some residues from the blasting agent. Nucleation mode particles (20 nm) contain Pb. These particles were also found on site 1.

Acknowledgements

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