Geochemical characterization of long-range transported volcanic particles from the Eyjafjallajökull eruption in Iceland

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Volcanic particles can be transported over long distances in the atmosphere and can cause severe problems for air traffic. This was the case over large areas of Europe in spring 2010 after the eruption of the Eyjafjallajökull (E15) volcano on Iceland. The focus of this work is a detailed geochemical and mineralogical characterization of single atmospheric particles collected in April 2010 at several ground-based sampling sites in Southwest Germany and to quantify which share of the overall atmospheric particles in Germany originated from the E15 eruption. To this end, single particle analysis by means of scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDX) and synchrotron radiation based micro X-ray fluorescence analysis (µS-XRF) together with multivariate statistical methods were applied for samples collected on ground-level in Southwest Germany and Iceland. Based on the obtained chemical fingerprints combined with multivariate statistical methods it was possible to discriminate between the amount of volcanic particles from Iceland and other atmospheric particles from non-volcanic sources.

Experimental

One part of the samples was collected in Germany at ground level (1.5 m height) as single particles on adhesive collection plates. These Sigma-2 samplers are located at background sites in the southwestern parts of Germany. There, atmospheric particulate matter (APM) is sampled regularly in a monitoring network of the German Meteorological Service (DWD). More details about the sampling with the Sigma-2 device can be found in [1,2]. Samples were collected during the event week when the volcanic ash reached Germany (16/04/2010 – 23/04/2010) as well as during the weeks before and after the volcanic particles reached Germany. The six sampling sites selected for detailed analyses are located in the city of Freiburg (300 m MSL), and at four remote sites in the Black Forest, Baiersbronn (585 m MSL), Bad Märgen (895 m MSL), Hinterzarten (885 m MSL) and Wolfach (305 m MSL), and as well as at the Schauinsland mountain (1200 m MSL). Moreover, also volcanic ash samples acquired directly from the Eyjafjalla in Iceland were analyzed as reference material. To do so, the particles were also placed on adhesive plates in order to provide comparable conditions for the comparison of the samples.

The adhesive collection plates can be used without any further preparation for µS-XRF analysis. The measurements were carried out under atmospheric conditions. Aerosol particles of a diameter between 1 and 10 µm have been measured by µS-XRF. Due to the very small particle size no concentrations but absolute element masses within the individual particles are obtained. To obtain a comparable fingerprint for the individual particles, the sum of the analyzed trace elements was normalized. At Beamline-L at the DORIS III synchrotron ring HASYLAB/DESY, the synchrotron radiation originates from positrons with 4.5 GeV at a bending magnet with a radius of 12.12 m. The critical energy is 16.6 keV. The excitation energy was adjusted to 20.7 keV by a Ni/C, Mo/Si multilayer monochromator. The incident beam was focussed to a diameter of 15 µm by using a cross-slit system and a subsequent polycapillary.

Results and Discussion

The chemical composition of individual particles measured by SEM-EDX and µS-XRF analysis was compared to the element composition of reference samples collected on Iceland near the volcano. With this approach, a characteristic fingerprint for the volcanic particles from the E15 volcano eruption was obtained (Figure 1) and it was then possible to discriminate between particles from the E15 and from other sources, such as traffic, industry, bare soils and other.

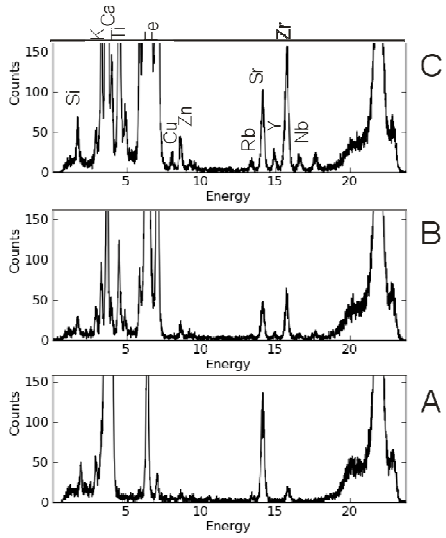

Figure 1: µS-XRF spectra measured as trace element fingerprints of (A) an ash fall out particle collected in Iceland close to the eruption site, (B) an ash fall out particle collected in the Black Forest, (C) a non-volcanic particle collected in the Black Forest.

From SEM-EDX and µS-XRF analysis it was estimated that about 40% of the analyzed particles within the size range of 2–10 µm in Southwest Germany were volcanic particles with the characteristic Eyjafjallajökull fingerprint. Cluster analysis helped to group the respective particle types from other sources. More details about the other cluster analysis can be found in [3]. About 30–40% of the analyzed particles could be clearly identified as volcanic particles from the E15 volcano. Highest concentrations were found at the Schauinsland with about 60% volcanic particles. The remote sites in the Black Forest showed lower contribution of volcanic particles but in general comparable results. The particles analyzed from Freiburg showed a much higher load of regional dust particles, which leads to a relative decrease of the amount of particles from volcanic origin.

Conclusively, it could be shown that volcanic particles from the E15 volcanic eruption reached the ground in Southwest Germany. Single particle analysis by means of SEM-EDX and µS-XRF provided a suitable fingerprint for the composition of the volcanic particles and enables the identification of probable mineral phases of the different particles and their type of sources. The study showed that the combination of single particle major and trace element analysis together with data evaluation by modern multivariate statistical methods, which were applied in this context for the first time, proved to be a good tool for the identification of the volcanic particles.

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