Chemical composition and shape of single aerosol particles generated from different Saharan soil samples during the "Mineral Dust Campaign 2008 – AIDA chamber facility, Karlsruhe"

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Introduction

Detailed knowledge of the mineralogical composition and morphology of particles is important to derive their optical properties and to interpret integral optical measurements of the aerosol ensemble. For this reason, samples from the aerosol chamber were collected with a miniature impactor system on a carbon adhesive. The size-resolved particle aspect ratio and chemical composition is determined by means of scanning and transmission electron microscopy and energy-dispersive X-ray micro analysis for particles between 50 nm and 1 µm in diameter. Mineralogical bulk composition of the parent soils was analyzed by X-ray diffraction analysis.

Details

Seven different samples have been investigated. The first one – clearly different from the North African samples – originates from Burkina Faso (BF). X-ray diffraction of sieved fractions (Fig. 1) shows a very high content of iron oxides (10 to 50 % mass for particles larger than 20 µm) with a hematite:goethite ratio of approximately 2:1. A quartz content of approximately 50 % was measured; the clay minerals illite, kaolinite and muscovite were identified, with kaolinite dominating. The other samples originate from Morocco and Egypt. The composition of these soils is rather similar. Besides a quartz content of approximately 40 %, 30 % of feldspars (albite and microcline) and 30 % clay minerals are found. The iron oxides content is below the detection limit (2 %).
The table below gives information on the sample nomenclature and the number of analyzed particle by electron-microscopic single particle analysis.

sample name	*sample desc.*	*no. of particles*
BF	**Burkina Faso**	682
B1	Samum B1	1214
B3a	**Samum B3**	846
B3b	**Samum B3**	207
Ka	Cairo 2	235
MO	**Morocco**	686
B2	**Samum B2**	108

Soil origin and composition

BF: wind-blown material near Dano, Burkina Faso (11°9.75'N 3°4.57'W)
B1: bank of Drâa Wadi 3 km W of M'Hamid, few vegetation (29°50.264'N 5°45.686'W)
B3a/b: border of salt flat/hamada SW of Ain Sidi Abd er Rahmane (29°51.721'N 6°9.406'W)
Ka: 50 km NE Cairo, close to Suez
MO: alluvial plain with vegetation near a paved road, 11 km N of Tendrara (33°10.33' N 2°0'W)
B2: serir, close to the Oued el Atach (29°50.974'N 6°0.905'W)

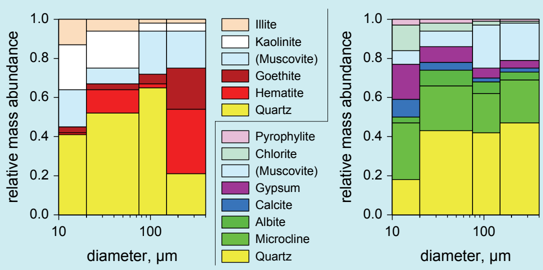

Fig. 1: Comparison of mineralogical soil composition for the Burkina Faso (left) and the Samum B3a (right) sample

Aerosol composition

The variation in the aerosol composition is significantly smaller than in the parent soils. While the bulk BF sample has an iron oxide content more than one order of magnitude higher than the B3a sample, this relation decreases to a factor of approximately 2 for the aerosol (Fig. 2). In the B3a sample, about 10 % of the particles are calcium-rich minerals (gypsum/anhydrite, dolomite and calcite). In contrast, these minerals are not observed in the BF sample. In general, the iron content of the silicate particles of the BF sample is higher than that of the B3a silicates by about 50 % relative (see Fig. 3, cluster around Si index 0.4). The average iron oxide content was calculated assuming a ratio of iron oxides to total iron of 1:3 and modeling the measured particle composition based on a four component model (quartz, silicates, iron oxide, calcite). For the BF sample, 2.8 % vol. of iron oxide were found, the North African samples ranged from 1.1 to 1.8 % vol. with a calcite content between 0 and 13 % vol.
In addition, in the BF sample a group of particles with approximately 200 nm diameter is observed which show a very high iron content (Fig. 4). These particles probably consist of a nanocrystalline iron oxide core with an amorphous silicate coating (Fig. 5). Spot test of the mineralogical phases of the crystallites in the core have shown the presence of hematite. Goethite could not be identified.
The shape of the particles is quite complex. However, it can be expressed as a two-dimensional aspect ratio by fitting an ellipse to the particle image outline. The overall resulting median value is 1.8 with low variations between the samples. This is significantly higher than values found for atmospheric mineral dust of 1.6, which is explained by the presence of chain-like particle aggregates in the former case. The iron-rich 200 nm particles mentioned above exhibit lower aspect ratios (1.57), and thus, the median aspect ratio of the BF sample is slightly lower than that of B3a.

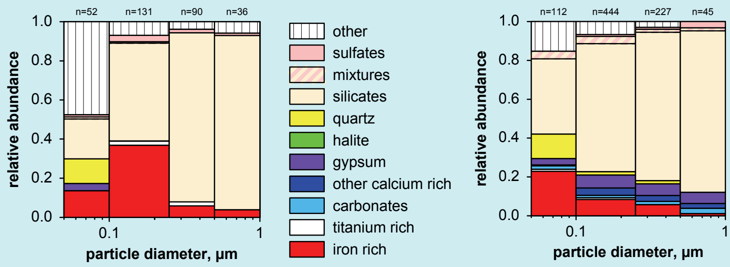

Fig. 2: Comparison of chemical/mineralogical composition for the Burkina Faso (left) and the Samum B3a (right) sample

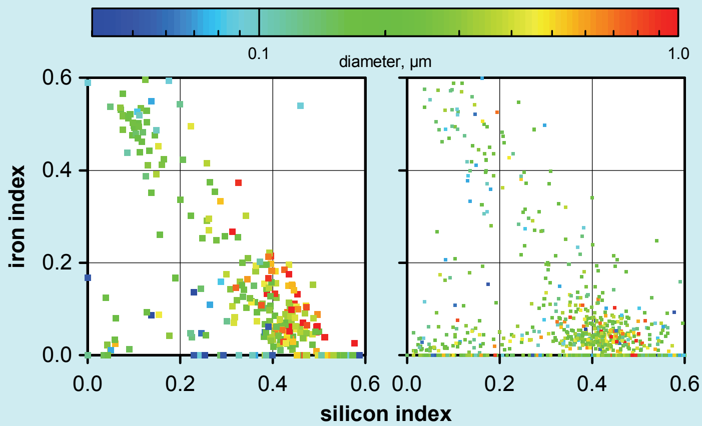

Fig. 3: Comparison of Fe/Si indices for the Burkina Faso (left) and the Samum B3a (right) sample

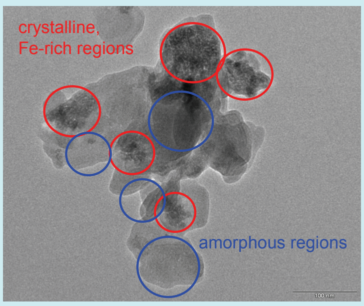

Fig. 4: Heterogeneous iron-rich particle

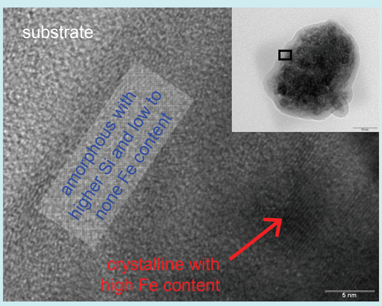

Fig. 5: Core/shell structure of a small iron-rich particle