Analysis of size classified aerosol particles collected in the Atlantic air from 50°N-30°S

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1. Introduction

The influence on climate, ecosystems and human health by atmospheric particles is undoubted but measurements to quantify the emission from natural and anthropogenic sources as well as the transport- and deposition behaviour are still incomplete.

Diverse natural sources are known to emit particles into the atmosphere, for instance volcanism, soil dust, vegetation burning, and sea spray. Additional an increasing number of anthropogenic sources emit particles into the atmosphere, like coal or oil combustion, refuse incinerators, industrial processes such as ore dressing etc. and transport processes including all mobile sources. These processes generate the predominant part of metallic trace elements bound to particles in the air. The composition of aerosol particles is determined by the course of chemical and physical reactions occurring in particle generation and transportation. In order to study such aspects as relevant sources, the transport of aerosols, their atmospheric deposition and their effects on man and environment, it is necessary to analyse different measurable properties of aerosol particles, for instance size distribution, chemical composition, isotope ratio, etc. Varying sampling conditions caused by changing meteorological conditions or sampling locations causes a need for short sampling times. Therefore powerful analytical techniques are imperative for time-resolved measurements.

In the present work aerosol particles were characterized for their morphological shape by scanning electron microscope (SEM) and analysed for the main components by energy dispersive x-ray analysis (EDXA). Trace elements were quantified more precisely by the application of electrothermal evaporation combined with inductively coupled plasma mass spectrometry (ETV-ICP-MS).

For application of ETV-ICP-MS to size fractionated particle analysis a modified eight-stage cascade impactor was used. Small separate graphite discs first act as an impaction target serve in a second step as a platform in the ETV and permit the particle analysis without any sample preparation.

The main goal of our investigations was to characterize the chemical composition of size fractionated aerosol particles as well as to quantify trace metal fluxes over the Atlantic Ocean (50°N-30°S) during leg ANT XVII/1 in Dec. 99/Jan. 2000 from Bremerhaven (FRG) to Cape Town (South Africa) on board R.V. Polarstern.

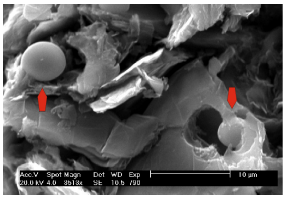
2.3. Aerosol characterisation by SEM/EDXA

Morphological characterisation of aerosol samples as well determination of main components were performed by SEM/EDXA.

3. Results

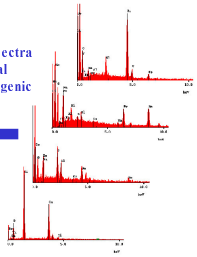
3.1. Morphological and main component determination by SEM/EDXA

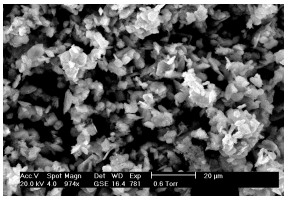
Typical aerosol particles from anthropogenic sources, sea salt as well as from mineral dust are shown together EDXA spectra in the following section. Single particle analysis show the source distribution for the northern- and southern hemisphere as well as for the region of Saharan dust.



SEM picture for typical anthropogenic particles from high temperature combustion processes Impactor 5 (4°S, 7°W), stage 16.5 µm.

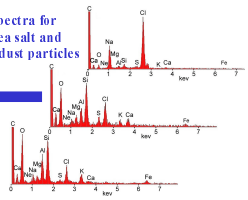
EDXA spectra for typical anthropogenic particles

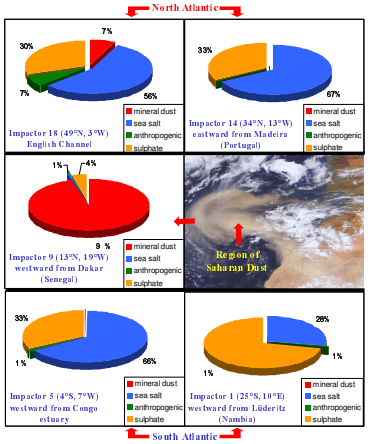




SEM picture for typical sea salt and mineral dust particles from the Saharan dust region Impactor 9 (13°N, 19°W), stage 3.45 µm.

EDXA spectra for typical sea salt and mineral dust particles





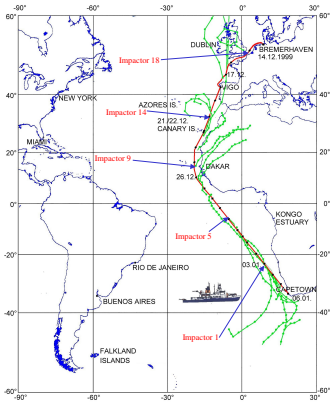
Regional and source distribution of the major components for aerosol particles in the Atlantic air analysed by SEM/EDXA

2. Experimental

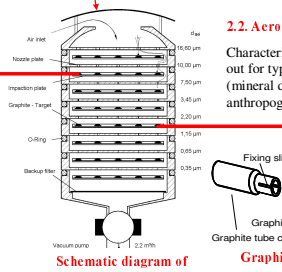
2.1. Aerosol sampling on board R.V. Polarstern

Aerosol sampling was carried out daily at the Peildeck in 22 m above sea level. The pump rate for the eight stage impactor was 2.2 m³/h. To avoid contaminations from the stack the equipment was shut down when the wind was blowing from the rear.

Aerosol sampling on board R.V. Polarstern



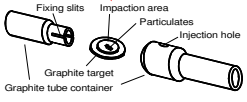
Course plot for ANT XVII/1 from 14.12.99-06.01.00 (red line) and 850 mbar backward trajectories (120 h, green lines)



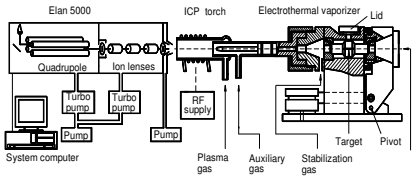
Schematic diagram of the cascade impactor

2.2. Aerosol characterisation by ETV-ICP-MS

Characterisation of aerosol samples was carried out for typical tracer elements by ETV-ICP-MS: (mineral dust: Mn, Cs, Sn; sea salt: Sb and In; anthropogenic sources: Pb and Ag).



Graphite tube for ETV-IVP-MS



Experimental setup for ETV-IVP-MS

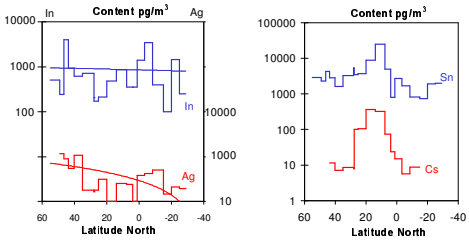
3.2. Trace element analysis by ETV-ICP-MS

Selected trace element concentrations measured by ETV-ICP-MS are shown in the following section. The constant distribution along the route for In seems to be an indicator that this element can be a tracer for sea salt. In contrast to that Ag represents a tracer for anthropogenic sources. Its concentration is higher in the more industrialized northern hemisphere. Sn and Cs represent tracer for geogenic elements. There are remarkable maxima in the innertropical convergence zone (5°-10°N), where east wind transports Saharan dust to the open ocean.

Measured isotope	^{55}Mn	^{59}Co	^{105}Pd	^{107}Ag	^{111}Cd	^{118}Sn
LOD pg/m³	1	0.8	0.2	0.03	0.2	0.5

Measured isotope	^{121}Sb	^{103}Rh	^{140}Ce	^{195}Pt	^{205}Tl	^{208}Pb
LOD pg/m³	1	0.1	3	0.6	0.05	0.2

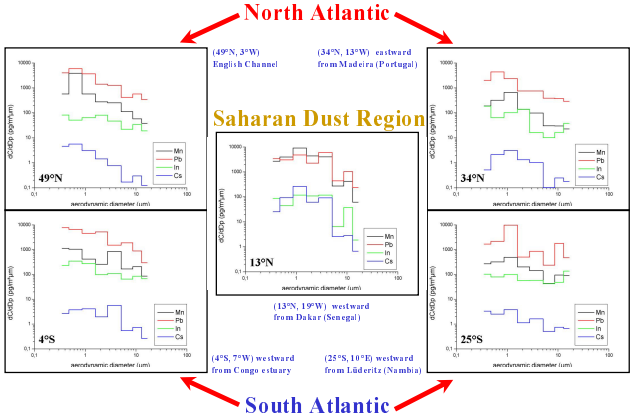
Limits of detection, based on the 3σ criteria



Spatial distribution for bulk element concentrations in aerosol particles over the Atlantic ocean from 50°N-30°S

Mean element concentrations in aerosol particles (pg/m³)

Element	North Atlantic Ocean 52°N - 22°N	Region of Saharan dust 22°N – 6°N	South Atlantic Ocean 6°N – 31°S
Ag	580 ± 130	220 ± 50	270 ± 50
Sb	1100 ± 290	300 ± 25	260 ± 60
Tl	28 ± 4	78 ± 20	16 ± 3
Sn	3950 ± 860	20800 ± 5100	1970 ± 470
Mn	3600 ± 870	15000 ± 2000	2480 ± 550
Pb	18200 ± 2800	18900 ± 1800	13600 ± 2600
Cs	21 ± 9	215 ± 65	21 ± 7
In	920 ± 300	520 ± 150	940 ± 300
Bi	250 ± 40	450 ± 50	200 ± 30



Spatial and size distribution of some selected trace elements in aerosol particles in the Atlantic air analysed by ETV-ICP-MS. Mn and Cs are tracers for mineral dust, In for sea salt and Pb represents anthropogenic influence. Trace element concentrations were normalized to the class widths of the eight impactor sampling stages.

4. Conclusions and Outlook

Size classified sampling of aerosol particles on separate graphite targets and subsequent multielement analysis is a useful tool for the characterization of aerosol particles. Morphological studies were carried out by SEM. Major element content of single particles were characterized by EDXA. Trace element concentrations were determined by ETV-ICP-MS directly from the aerosol loaded graphite targets.

The high efficiency of the sampling system combined with the powerful analytical technique permits the study of isotope correlations allowing the identification of particle sources as well as transport and deposition processes in a high time and spatial resolution.

Further improvements can be expected by using time of flight (TOF) mass spectrometer. TOF-instruments work truly simultaneously and are not limited in the number of measurable isotopes in fast transient signals.

5. Acknowledgement

We would like to thank T. Adam and U. Bock (AWI) for assistance in SEM operation and EDX analysis. Many thanks to the crew of R.V. Polarstern for their help in setting up our instruments and providing logistical support. The financial support given by the DFG is gratefully acknowledged.