

# Source Identification of Airborne Particulate Matter by Use of Impactor Measurements

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## Summary

By use of impactors fractionated particulate matter was collected at sites of different air quality (rural, urban, road-side). Furthermore, this was done near characteristic sources (at city-streets, industrial areas, farm-soils, forests, ocean coasts). The mass fractions were analysed by several analytical methods in order to determine size distributions of organic and inorganic substances. It was found that every particulate specie is related to a specific Mass Median Diameter (MMD) which was largely invariant among the different sampling sites. By comparison of emission- and immission measurements the contributions of the different sources can be assessed. It was seen that not only primary aerosol substances have specific MMD's but also secondary aerosol substances. Thus, the mass contributions of secondary aerosols can also be assessed.

## Method and Discussion

In steady state the emission rate  $E_i$  of an atmospheric substance  $m_i$  equals its removal rate  $R_i$  (1).  $\tau_i$  is the atmospheric residence time.

$$(1) \quad E_i = \frac{m_i}{\tau_i} = R_i$$

The mass  $m_i$  can be related to its concentration  $c_i$  with the application of the mixing height  $H$  and the extent  $F$  of the regarded earth surface:

$$(2) \quad E_i = \frac{c_i \cdot H \cdot F}{\tau_i}$$

With the aid of an 8-stage Andersen impactor the size-fractionated concentrations  $c_i$  of many substances by use of GC-FID, GC-ECD, GC-MS, IC, AAS, ICP-MS, PIXE and NA were measured.

It was found that every particulate substance has a specific MMD which is largely invariant of the different sampling sites. This MMD is related with the residence time  $\tau_i$  which results of the reciprocal addition of the dry residence  $\tau_{i \text{ dry}}$  and the wet residence time  $\tau_{i \text{ wet}}$ .

$$(3) \quad \frac{1}{\tau_i} = \frac{1}{\tau_{idry}} + \frac{1}{\tau_{iwet}}$$

$$(4) \quad \frac{1}{\tau_{idry}} = \frac{v_o}{2H} \left[ \left( \frac{MMD}{d_o} \right)^2 + \left( \frac{d_o}{MMD} \right)^2 \right]$$

Under Middle European conditions the constants have the following yearly average values:

$$v_o = 0,1 \text{ cm/s}; \quad H = 1000 \text{ m}; \quad d_o = 0,6 \mu\text{m}$$

$\tau_{i \text{ wet}}$  can be considered to be 6 days in the yearly mean under Middle European conditions (2).

In the case of secondary aerosols the residence time of the precursor gases have also to be taken into account.

$$(5) \quad \tau_i = \tau_{ig} + \alpha \cdot \tau_{ip}$$

$\tau_{ig}$  is the residence time of the precursor gas and  $\tau_{ip}$  the residence time of the secondary particulate mass.  $\alpha$  is the conversion factor which was found to be 0,15 for the mean conversion of SO<sub>2</sub> into particulate sulfate (3).

In Tab. 1 the MMD's of several particulate substances as a result of many impactor measurements are listed.

In Tab. 2 the main substances of PM<sub>10</sub> and PM<sub>2,5</sub>, the primary and secondary PM-fractions and the anthropogene and natural contributions are listed.

## References

Müller, J. (1996). VDI Berichte Nr. 1257 (c/o VDI, Düsseldorf, ISBN 3-18-091257-X), 591-596

Jaenicke, R. (1978). Bericht Bunsengesellschaft Physikalische Chemie 82, 1198-1202

Müller, J. (1985). WMO-No. 647, Report TECOMAC (c/o WMO, Geneva), 173-176

**Table 1:** Mass Median Diameters (MMD's) of airborne particulate substances

<b>MMD (<math>\mu\text{m}</math>)</b>	<b>Particulate substances</b>
0,1 – 0,2	H <sub>2</sub> SO <sub>4</sub> , SbBr <sub>2</sub>
0,2 – 0,4	NH <sub>4</sub> NO <sub>3</sub>
0,4 – 0,6	AlCl <sub>3</sub> , Cr(VI)O <sub>3</sub> , FeCl <sub>3</sub> , KHSO <sub>4</sub> , TiNO <sub>3</sub> , BbF
0,6 – 0,8	CHR, BkF, BaP, BeP
0,8 – 1,0	NaNO <sub>3</sub> , U <sub>3</sub> O <sub>8</sub> , PER, BghiP, DahA
1,0 – 1,2	As <sub>2</sub> O <sub>3</sub> , COR
1,2 – 1,4	As <sub>2</sub> S <sub>3</sub> , Cd(met.), PtO <sub>2</sub> , ZnCl <sub>2</sub>
1,4 – 1,6	KNO <sub>3</sub> , TiCl
1,6 – 1,8	PbO
1,8 – 2,0	NH <sub>4</sub> Cl, (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> , PbCl <sub>2</sub> , PbBr <sub>2</sub>
2,0 – 2,2	CdCl <sub>2</sub>
2,2 – 2,4	AlF <sub>3</sub> , CuCl <sub>2</sub> , Sb <sub>2</sub> S <sub>3</sub> , ThCl <sub>4</sub>
2,4 – 2,6	CoCl <sub>2</sub> , KOH, Sr(NO <sub>3</sub> ) <sub>2</sub>
2,6 – 3,0	CuCl, Fe <sub>2</sub> O <sub>3</sub> , MnCl <sub>2</sub> , MnSO <sub>4</sub> , Pb(met.), PdCl <sub>2</sub> , Ti <sub>2</sub> O <sub>3</sub>
3,0 – 3,5	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> , KCl, MgCl <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaCl, NiS
3,5 – 4,0	CaCO <sub>3</sub> , CaSO <sub>4</sub> , K <sub>2</sub> CO <sub>3</sub> , Na <sub>2</sub> O, Na <sub>2</sub> SO <sub>4</sub> , PdS, RuO <sub>2</sub> , V <sub>2</sub> O <sub>5</sub>
4,0 – 4,5	CaCl <sub>2</sub> , CdSO <sub>4</sub> , CdS, CoSO <sub>4</sub> , K <sub>2</sub> SO <sub>4</sub> , LaCl <sub>2</sub> , NiCl <sub>2</sub> , PbSO <sub>4</sub> , SrCl <sub>2</sub>
4,5 – 5,0	CrCl <sub>3</sub> , MgSO <sub>4</sub> , PbS, RhO
5,0 – 5,5	CdO, Cu <sub>2</sub> O, Fe <sub>2</sub> SiO <sub>4</sub>
5,5 – 6,0	CuO, Cu(met.)
6,0 – 6,5	
6,5 – 7,0	Fe <sub>3</sub> O <sub>4</sub> , La(met.), Mn <sub>3</sub> O <sub>4</sub> , Ni(met.), SrSO <sub>4</sub>
7,0 – 7,5	Fe(met.), SiO <sub>2</sub> , TiO <sub>2</sub>
7,5 – 8,0	Al <sub>2</sub> O <sub>3</sub> · 3SiO <sub>2</sub> , CoO, MnO <sub>3</sub> , Ti(met.)
8,0 – 8,5	NiO, Pd(met.), Ti <sub>2</sub> O <sub>3</sub>
8,5 – 9,0	Al <sub>2</sub> O <sub>3</sub> , Cr <sub>2</sub> O <sub>3</sub> , SrO, VO, ZnO
9,0 – 9,5	Rh(met.)
9,5 – 10,0	CaO, Pt (met.)
10,0 – 10,5	La <sub>3</sub> O <sub>3</sub>
10,5 – 11,0	Ir(met.), Ru(met.)
11,0 – 11,5	
11,5 – 12,0	ThO <sub>2</sub>
12,0 – 12,5	MgO, UO <sub>2</sub>

**Table 2:** Substances in PM<sub>10</sub> and PM<sub>2,5</sub> in urban background, primary and secondary PM-fractions and anthropogene and natural contributions

<b>PM<sub>10</sub></b> <b>Urban residential</b>	<b>Mass fractions</b>		<b>anthropogene</b>	<b>natural</b>
Yearly mean 2001;  24 µg/m <sup>3</sup>	Primary Combustion	35 %	35 %	0 %
	Primary rest	30 %	20 %	10 %
	Secondary	35 %	30 %	5 %
		100 %	85 %	15 %

<b>PM<sub>2,5</sub></b> <b>Urban residential</b>	<b>Mass fractions</b>		<b>anthropogene</b>	<b>natural</b>
Yearly mean 2001;  18 µg/m <sup>3</sup>	Primary Combustion	45 %	45 %	0 %
	Primary rest	10 %	7 %	3 %
	Secondary	45 %	39 %	6 %
		100 %	91 %	9 %

<b>Components</b>	<b>PM<sub>10</sub></b>	<b>PM<sub>2,5</sub></b>
Mass (yearly mean)	24 µg/m <sup>3</sup>	18 µg/m <sup>3</sup>
Sulfate SO <sub>4</sub>	16 %	19 %
Nitrate NO <sub>3</sub> <sup>-</sup>	12 %	12 %
Ammonium NH <sub>4</sub> <sup>+</sup>	9 %	12 %
Cloride Cl <sup>-</sup>	2 %	1 %
Metal-ions: Na <sup>+</sup> , K <sup>+</sup> , Ca <sup>2+</sup> , Mg <sup>2+</sup>	5 %	4 %
Organic Carbon (OC)	18 %	22 %
Elementary Carbon (EC)	13 %	16 %
Metaloxides, Minerals	18 %	6 %
Water and Rest	7 %	8 %
	100 %	100 %