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ABSTRACT

The blank values of 30 elements in 19 different filter types from Gelman, Millipore, Nuclepore and Whatman have been compared. The filter media were extracted with dilute nitric acid and the element contents determined by ICP-MS. Large differences in blank values were observed between different filter materials. Glass fiber filters showed high blank values for a number of elements, whereas PTFE filters generally were the cleanest. However, most filter types showed high blank values of one or more elements of interest in aerosol measurements.

CONTENTS

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1 INTRODUCTION

For sensitive analytical techniques such as inductively coupled plasma mass spectrometry (ICP-MS), the lowest amount of an element which can be determined is affected by the procedure blank (the value obtained from blank samples which are taken through the same sample preparation procedure as the samples). Such a blank value is often referred to as the field blank and depends on:

- purity of the reagents used
- possible contamination during the sample preparation procedure
- presence of the element in sampling equipment such as air filters

The two first items above can usually be controlled by using high purity reagents and careful preparation procedures. The background value coming from the filter material may contribute much stronger to the total blank value, and is often the dominant source of the field blank. The blank values coming from the filter materials are therefore important to consider in order to select the filters best suited for determination of elements in air.

In this work 19 filter types from four manufacturers (Gelman, Millipore, Nuclepore and Whatman) were compared. Most of the filter materials studied in this work are recommended for the collection of particles in air.

ICP-MS is a powerful analytical technique for the determination of trace elements (Thompson and Walsh, 1989). It is possible to determine most elements of environmental interest with detection limits below 1 ng/ml. ICP-MS was used in this work to determine the blank values of 30 elements in the different filter materials investigated.

2 EXPERIMENTAL

2.1 PREPARATION OF THE FILTERS

The 19 different filters selected are shown in Table 1.

About ten filters of each type were extracted with 10 ml, 0.2 M nitric acid (Merck, Suprapur) and 50 ng In pr ml was added as internal standard. To get the same conditions for all filters, the samples were stored two days before analysis.

Table 1: Filter materials investigated

Manufacturer	Type	Filter material	Remarks		No.
			Pore size (μm)	Diameter (mm)	
Gelman Sciences	Zefluor	Membrane PTFE	2	47	2
Gelman Sciences	TF-1000	Membrane PTFE/polypropylene	1	47	1
Gelman Sciences	GN-4 Metricel	Membrane cellulose esters	0.8	47	5
Gelman Sciences	DM Metricel	Membrane vinyl/acryl copolymer	0.8	47	9
Gelman Sciences	Verspor 1200	Membrane acryl/nylon copolymer	1.2	50	12
Gelman Sciences	Supor-800	Membrane polysulfone	0.8	47	11
Gelman Sciences	GLA-5000	Membrane PVC	5	47	10
Gelman Sciences	A/E	Glass fiber		47	16
Millipore	FALP 04700	Membrane PTFE/polyethylene	1	47	3
Millipore	AAWP 04700	Membrane cellulose esters	0.8	47	6
Nuclepore	fn memb	Membrane PTFE/polypropylene	1.0	47	4
Nuclepore	mf memb	Membrane cellulose esters	0.8	47	7
Nuclepore	pc memb	Membrane polycarbonate	0.8	47	13
Nuclepore	pc memb	Membrane polycarbonate (apiezon coated)	8	47	14
Nuclepore	PVC memb	Membrane PVC	0.8	37	15
Whatman	WCN	Membrane cellulose nitrate	1.0	47	8
Whatman	W 40	Cellulose		47	19
Whatman	GF/A	Glass fiber		37	17
Whatman	QM-A	Quartz fiber		47	18

2.2 INSTRUMENTATION AND ANALYSIS

The ICP-MS used in this work was a Plasma Quad I from VG Elemental. The solutions were introduced by a peristaltic pump (Ismatec Reglo 100), and a concentric Meinhard nebulizer was used. Some of the most important instrument operating conditions are shown in Table 2.

Table 2: ICP-MS Operating Conditions.

Plasma Conditions	
rf power	1.35 kW
plasma gas flow	13 l/min
auxiliary gas flow	0.4 l/min
nebulizer gas flow	0.7 l/min
Solution uptake rate (Ismatec Reglo 100)	1.0 ml/min
Optimisation	max. signal ^{115}In
Data acquisiton	scan mode
number of channels in the MCA	2048
dwell-time	600 μs
number of sweeps	100

The sensitivity of the instrument was optimized with a 5 ng/ml In solution by varying the ion lens voltages so as to maximize the ^{115}In signal. Calibration was accomplished by using a blank and a standard solution, the concentration of which was close to that estimated for the analyte considered. The calibration standards were prepared by appropriate dilutions of a multi-element stock solution (Teknolab As, N-1440 Drøbak) which contained the elements listed in Table 3. All calibration standards and blanks contained 0.1 M HNO_3 and 50 ng In per ml (internal standard). The samples were introduced from an autosampler with standards and blanks interspersed at regular intervals (respectively every 10 and 5 samples). With a data acquisiton memory group of 2048 channels, a dwell-time of 600μs and 100 sweeps, each spectrum was accumulated approximately for 2 min.

Table 3: Isotopes used and instrumental detection limits (in ng/ml).

Element	Mass	IDL*
Li	7	0.1
Be	9	0.1
B	11	1
Na	23	50
Mg	25	15
V	51	0.1
Cr	52	1
Mn	55	0.2
Fe	57	100
Co	59	0.05
Ni	58	0.5
Cu	65	0.4
Zn	64	0.3
Ga	71	0.1
As	75	0.5
Rb	85	0.05
Sr	88	0.01
Y	89	0.02
Mo	95	0.1
Cd	111	0.1
Sb	121	0.05
Te	125	1
Cs	133	0.03
Ba	138	1
La	139	0.03
Tl	205	0.02
Pb	208	0.1
Bi	209	0.02
Th	232	0.01
U	238	0.01

*Instrumental detection limits

The instrumental detection limit reported from the instrument software may change from day to day. The detection limit is defined by the software from the measured background and the sensitivity for each element. Because we wanted to operate with the same detection limit for each element for all filter types, the highest reported detection limit for each element studied was used. These detection limits are given in Table 3. As seen from Table 3, ICP-MS has poor sensitivity for Na, Mg and Fe. For Na and Mg this is due to contamination of the sample and skimmer cone throughout the analysis causing high background counts. The most abundant Fe isotope, ^{56}Fe, is subject to interference by spectral overlap from ArO, and the selected isotope ^{57}Fe has an abundance of only 2.14%.

2.3 STATISTICAL ANALYSIS OF THE RESULTS

SPSS-X (Statistical Package for the Social Sciences) was employed to analyse the obtained data statistically (SPSS Inc., 1988) For each filter type the following parameters were calculated: mean, minimum, maximum, standard deviation and number of samples below the detection limit. In cases where some values obtained for one filter type were below the detection limit, a figure equal to half the detection limit was used when calculating the mean and the standard deviation.

3 RESULTS

In the following the mean values and standard deviations of the blank values are tabulated for comparision of the various filter materials (Tables 4-7). In the appendix additional information (minimum, maximum, relative standard deviation, number of samples, number of measurements below the detection limit) is given for each filter type.

Before statistical analysis the results obtained were multiplied by the extraction volume of 10 ml. The statistical analysis was thus performed on the amount of each element extracted from each filter.

The concentrations are given as ng per filter. All but three of the filter types have 47 mm diameter. For comparison the values for the three remaining filter types were adjusted to 47 mm.

Table 4: Elements in membrane filters (polytetrafluoroethylene - PTFE): Mean values ($\bar{x}$) and standard deviations (s) (ng per filter).

ELEMENT	1 GELMAN TF-1000 (66155)		2 GELMAN zefluor (P5PJ047)		3 MILLIPORE fluoropore (FALP 04700)		4 NUCLEPORE fn-memb (131110)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Li	< 1	0.6	< 1	-	< 1	-	< 1	-
Be	< 1	-	< 1	-	< 1	-	< 1	-
B	< 10	4.0	< 10	-	< 10	-	< 10	-
Na	< 500	-	< 500	-	< 500	-	< 500	-
Mg	28	33	180	140	140	56	300	90
V	< 1	0.3	< 1	-	< 1	-	< 1	-
Cr	7	1.0	35	10	21	7	85	7
Mn	< 2	-	< 2	-	< 2	-	< 2	1.0
Fe	<1 000	-	<1 000	-	<1 000	-	<1 000	-
Co	< 0.5	-	< 0.5	-	< 0.5	-	< 0.5	-
Ni	< 5	-	< 5	-	< 5	-	< 5	-
Cu	< 4	-	< 4	-	< 4	-	7	3.4
Zn	< 3	1.8	< 3	3.0	7	2.3	18	4
Ga	< 1	-	< 1	-	< 1	-	< 1	-
As	< 5	-	< 5	-	-	-	-	-
Rb	< 0.5	0.2	< 0.5	-	< 0.5	-	< 0.5	-
Sr	< 0.1	0.1	0.3	0.2	0.2	0.1	200	12
Y	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-
Mo	< 1	-	< 1	0.7	< 1	-	< 1	-
Cd	< 1	0.7	< 1	0.8	< 1	-	< 1	0.6
Sb	< 0.5	-	< 0.5	-	< 0.5	-	3	0.4
Te	< 10	-	< 10	-	< 10	-	< 10	-
Cs	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-
Ba	3	4.4	2	2.0	2	0.5	4	1.7
La	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-
Tl	0.8	0.8	< 0.2	-	< 0.2	-	< 0.2	-
Pb	< 1	1.3	< 1	2.4	< 1	-	< 1	1.1
Bi	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-
Th	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
U	< 0.1	-	-	-	< 0.1	-	< 0.1	-

Table 5: Elements in membrane filters (mixed esters of cellulose): Mean values ($\bar{x}$) and standard deviations (s) (ng per filter).

ELEMENT	5 GELMAN GN-4 (64679)		6 MILLIPORE MF (AAWP 04700)		7 NUCLEPORE membra-fil (141109)		8 WHATMAN WCN (7190 004)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Li	< 1	-	< 1	-	< 1	0.8	< 1	-
Be	< 1	-	< 1	-	< 1	-	< 1	-
B	< 10	-	16	1	< 10	-	18	3
Na	15000	980	6 700	160	9 700	170	3 000	250
Mg	130	98	200	35	310	280	650	240
V	< 1	-	< 1	0.3	< 1	-	< 1	-
Cr	290	26	51	4.0	320	42	300	88
Mn	< 2	0.6	3	0.4	13	1	< 2	-
Fe	<1 000	-	<1 000	-	<1 000	-	<1 000	-
Co	< 0.5	-	< 0.5	-	< 0.5	-	< 0.5	-
Ni	< 5	-	< 5	1.3	< 5	-	< 5	-
Cu	19	19	24	1	57	4	5	1.6
Zn	31	17	330	17	160	65	32	17
Ga	< 1	-	< 1	-	< 1	-	< 1	-
As	< 5	-	-	-	< 5	-	< 5	1.3
Rb	< 0.5	-	1	0.1	< 0.5	-	1	0.2
Sr	0.8	0.2	2	0.2	3	0.2	14	2
Y	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-
Mo	< 1	-	< 1	-	< 1	-	< 1	-
Cd	< 1	-	< 1	-	< 1	-	< 1	-
Sb	< 0.5	-	< 0.5	-	< 0.5	-	< 0.5	-
Te	< 10	-	< 10	-	< 10	-	< 10	-
Cs	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-
Ba	< 1	-	4	0.7	6	1.2	4	1.2
La	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-
Tl	< 0.2	-	< 0.2	-	< 0.2	-	0.4	0.1
Pb	< 1	-	7	2.0	< 1	-	3	2.8
Bi	< 0.2	-	< 0.2	-	< 0.2	0.1	< 0.2	-
Th	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
U	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-

Table 6: Elements in membrane filters of other materials: Mean values ($\bar{x}$) and standard deviations (s) (ng per filter).

ELEMENT	9 GELMAN DM metricel (vinyl/acryl) (64502)		10 GELMAN GLA-5000 (PVC) (66468)		11 GELMAN SUPOR-800 (polysulfone) (60110)		12 GELMAN Versapor (acryl/nylon) (4600000)		13 NUCLEPORE (poly-carbonate) (111109)		14 NUCLEPORE (poly-carbonate/AP) (111132)		15 NUCLEPORE (PVC) (361550)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Li	< 1	0.6	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-
Be	< 1	0.8	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-
B	< 10	-	-	-	< 10	-	< 10	-	< 10	-	< 10	-	< 10	-
Na	6 700	240	11 000	2000	12000	490	5 800	980	< 500	-	< 500	-	3 400	3000
Mg	1 600	80	64	71	1200	360	1 100	360	80	63	230	220	420	210
V	< 1	-	2	0.5	< 1	-	41	4	< 1	-	< 1	-	2	0.7
Cr	190	16	91	39	360	40	290	45	460	170	130	14	29	5
Mn	3	0.5	3	0.9	5	0.5	8	2.0	< 2	-	< 2	-	24	10
Fe	<1 000	-	<1 000	-	<1 000	-	<1 000	-	<1 000	-	<1 000	-	<1 000	-
Co	< 0.5	-	< 0.5	-	< 0.5	-	0.7	0.2	< 0.5	-	< 0.5	-	< 0.5	0.4
Ni	< 5	-	< 5	-	< 5	-	11	12	< 5	-	< 5	-	< 5	3.0
Cu	59	41	5	2.8	6	1.1	2 400	190	< 4	-	< 4	1.1	320	150
Zn	45	28	32	7	21	5	77	15	13	2.8	9	4.8	73	37
Ga	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-
As	< 5	-	< 5	-	< 5	-	10	2.3	< 5	-	< 5	-	< 5	-
Rb	< 0.5	0.1	< 0.5	-	< 0.5	0.2	< 0.5	0.2	< 0.5	-	< 0.5	-	< 0.5	-
Sr	16	1	2	0.4	3	0.2	7	1.4	0.3	0.1	0.3	0.2	10	3.2
Y	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	0.1
Mo	< 1	0.7	< 1	-	< 1	-	50	7	< 1	-	< 1	-	< 1	-
Cd	16	20	< 1	0.5	< 1	-	< 1	1.0	< 1	-	< 1	-	< 1	-
Sb	< 0.5	-	< 0.5	-	< 0.5	-	< 0.5	0.3	< 0.5	-	< 0.5	-	< 0.5	-
Te	< 10	-	< 10	3.1	< 10	-	< 10	-	< 10	-	< 10	-	< 10	-
Cs	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-
Ba	10	1.2	< 1	-	3	0.8	5	2.1	2	2.5	< 1	-	6	2
La	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-	< 0.3	-	0.9	0.8
Tl	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-
Pb	2	1.6	< 1	-	3	0.4	4	0.3	< 1	2.5	< 1	-	23	8
Bi	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	0.1	< 0.2	-
Th	< 0.1	-	0.3	0.1	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
U	< 0.1	-	< 0.1	0.05	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	0.1

Table 7: Elements in fiber filters: Mean values ($\bar{x}$) and standard deviations (s) (ng per filter).

ELEMENT	16 GELMAN A/E (glass) (61631)		17 WHATMAN GF/A (glass) (1820 037)		18 WHATMAN QM/A (quarts) (1851 047)		19 WHATMAN W 40 (cellulose) (1440 047)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Li	24	6	11	1.1	< 1	-	< 1	-
Be	3	3.6	< 1	0.5	< 1	-	< 1	-
B	5100	860	21000	2300	160	19	32	2
Na	80000	8000	100000	5800	37000	1200	4 000	760
Mg	940	140	2400	210	1800	250	390	92
V	3	1.4	8	1.0	< 1	-	2	0.3
Cr	71	12	65	6	110	33	7	0.6
Mn	19	5	12	4.2	4	1.0	< 2	1.5
Fe	2000	650	< 1000	-	<1 000	-	<1 000	-
Co	< 0.5	0.5	< 0.5	-	< 0.5	-	< 0.5	-
Ni	< 5	-	13	2.1	< 5	1.3	10	1.1
Cu	35	23	50	15	11	5	110	45
Zn	11000	1600	36000	3200	68	29	22	12
Ga	-	-	-	-	< 1	-	< 1	-
As	8	11	< 5	-	< 5	-	-	-
Rb	320	26	180	10	0.8	0.3	< 0.5	-
Sr	250	28	900	68	18	1.5	10	2.1
Y	0.5	0.7	0.5	0.2	0.3	0.1	< 0.2	-
Mo	2	2.5	< 1	-	6	1.5	< 1	-
Cd	< 1	1.7	2	1.1	< 1	-	< 1	-
Sb	2	1.0	3	0.6	1	0.3	< 0.5	-
Te	< 10	-	< 10	-	< 10	-	< 10	-
Cs	16	2	6	0.5	< 0.3	-	< 0.3	-
Ba	15000	1800	44000	3100	30	9.4	16	6
La	1	0.5	2	0.2	< 0.3	-	< 0.3	-
Tl	1	0.4	2	0.2	< 0.2	-	< 0.2	-
Pb	62	6	55	16	9	4.8	8	6
Bi	< 0.2	0.3	< 0.2	-	0.6	0.7	< 0.2	-
Th	0.3	0.3	< 0.1	0.05	< 0.1	-	< 0.1	-
U	-	-	< 0.1	0.05	< 0.1	-	< 0.1	-

4 DISCUSSION

4.1 DEFINITION OF LIMIT OF DETECTION

The limit of detection (LOD) is a number, expressed in units of concentration (or amount), that describes the lowest concentration level (or amount) of the element that an analyst can determine to be statistically different from an analytical blank (Winefordner <u>et al</u>., 1983). The LOD in most analytical methods is based on the relationship between the gross analytical signal M, the mean of the field blanks $\bar{x}_B$ and the standard deviation of the field blanks σ_B. This relationship can be expresssed as:

$$M \geq LOD \qquad (1)$$

where

$$LOD = \bar{x}_B + k * \sigma_B \qquad (2)$$

so that

$$M - \bar{x}_B \geq k * \sigma_B \qquad (3)$$

and k is a constant.

The accuracy in the determination of LOD improves with the increasing number of measurements. If the number of replications is limited, it is important to increase the factor k to prevent serious underestimation of LOD. For this purpose, the Student's t distribution can be used.

The measured standard deviation s_B converges to the "true value" σ_B only after a large number of measurements (McDougall <u>et al</u>., 1980). Thus, Student's t-factor which can be obtained from tables of t-distribution depends on the number of samples (degrees of freedom) and the probability level desired. At 10 degrees of freedom the t-factor is about 1.81 and 2.76 at a probability level of 95 and 99% respectively.

Instead of this statistical definition it is recommended that detection should be based on a minimum value of 3 for t. Thus the LOD is located at 3σ above the gross blank signal. While a value of t=3 is considered a minimum, higher values may be required to obtain the desired statistical confidence (Mc. Dougall <u>et al.</u>, 1980).

It seems that in order to use such a simplified approach it is necessary to estimate $\bar{x}_B$ and s_B from a number of samples of at least 5-10. If ten samples are used, a factor of 2 corresponds to a probability level of about 95% and a factor of 3 to about 99% (Bhattacharyya and Johnson, 1977). However, this statistical argument is based on normality of the distribution of the blank values, which in practice may be violated. From the law of large numbers, it is possible to estimate the probability level to be over 89 and 75% for k=3 respectively 2, in the worst case (Kaiser, 1970).

In order to make accurate measurements at low levels it is desirable that the blank value can be estimated with high accuracy. In most cases this is best achieved if the blank value is low, as the absolute value of the standard deviation normally increases with the magnitude of the blank value. Otherwise the uncertainty of the blank value estimate can be decreased by analysing more blank samples, but this is usually inconvenient.

In order to decide which filter material is best suited for sampling of trace metals in air at low levels there are thus two parameters which are important to determine:

- mean value of the blank (to make accurate measurements at low levels)
- standard deviation of the blank value (to estimate the detection limit)

4.2 TYPICAL LEVELS OF ELEMENTS IN AIR PARTICLES AT REMOTE AREAS

It is necessary to have in mind the expected concentration levels of elements when considering different filter types for aerosol sampling. Table 8 is therefore included in order to show typical concentrations of elements in air particles at two remote stations, Vadsø and Ny-Ålesund (Maenhaut et al. 1989).

Table 8: Median values of the atmospheric trace element concentrations (in ng/m^3) at two remote stations.

ELEMENT	Vadsø	Ny-Ålesund
Li		
Be		
B		
Na	490	230
Mg	64	48
Sc	0.0030	0.0043
V	1.68	0.54
Cr	0.65	<0.4
Mn	0.97	0.77
Fe	27.0	17.8
Co	0.032	0.0096
Ni	1.20	0.29
Cu	1.09	<0.9
Zn	6.1	3.9
Ga	<0.23	<0.15
As	0.97	0.52
Rb	0.144	0.083
Sr	<1.0	<1.1
Y		
Mo	<0.2	<0.14
Cd	0.119	0.080
Sb	0.120	0.092
Te		
Cs	0.0126	0.0089
Ba	<2.5	<1.5
La	0.0127	0.0137
Tl		
Pb	5.6	3.0
Bi		
Th	0.0032	0.0037
U		

In general the following concentration levels of elements in air particles may be observed in remote areas:

< 0.1 ng/m^3 : Li, Be, Co, Ga, Rb, Y, Mo, Cd, Sb, Cs, La, Tl, Bi, Th, U

0.1-10 ng/m^3 : B, V, Cr, Mn, Ni, Cu, Zn, As, Sr, Ba, Pb

> 10-1000 ng/m^3 : Na, Mg, Fe

4.3 SUITABILITY OF THE ANALYSED FILTERS FOR TRACE ELEMENT WORK

The equations 1-3 (Page 14) shows that the standard deviation of the blank value is the main factor which determines the suitability of the filter. Filter types with a high mean value of an element may be used if the standard deviation is low. A low aerosol concentration combined with background levels of elements in the filters, makes it necessary for large volumes of air to be sampled in order to collect sufficient material for an accurate analysis. The following discussion is based on a sample volume of 50 m^3, which is a quite large sample volume for the analysed filter types.

Table 9 gives a survey of the suitability of the different filters. The table is based on the lowest trace element concentrations measured at Vadsø or Ny-Ålesund and on a sample volume of 50 m^3. Only elements measured at Vadsø or Ny-Ålesund at concentrations higher than the detection limits are rated in the table. The ratings are defined as follows:

A: Very suitable	$M > 10$ LOD
B: Suitable	5 LOD $< M <$ 10 LOD
C: Marginal	LOD $< M <$ 5 LOD
D: Unsuitable	$M <$ LOD

The equations above are explained on page 14. In cases where 50% or more of the measured filter blanks were below the detection limit for ICP-MS (IDL), this is also marked in the table. In these cases the sensitivity of the ICP-MS is the limiting factor. These ratings are marked as follows:

X: ICP-MS Suitable	5 IDL $< M <$ 10 IDL
Y: ICP-MS Marginal	IDL $< M <$ 5 IDL
Z: ICP-MS Unsuitable	$M <$ IDL

Table 9: Suitability of the different filters. A: Very suitable, B: Suitable, C: Marginal, D: Unsuitable, X: ICP-MS Suitable, Y: ICP-MS Marginal, Z: ICP-MS Unsuitable

ELEMENT	FILTER																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Li																			
Be																			
B																			
Na	A	A	A	A	C	A	A	A	A	C	B	C	A	A	C	D	D	C	B
Mg	A	B	A	B	B	A	C	C	A	A	C	C	A	C	C	B	C	C	B
V	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	B	B	A	A
Cr	A	C	C	C	D	C	D	D	D	D	D	D	D	D	C	D	C	D	A
Mn	A	A	A	A	A	A	A	A	A	A	A	B	A	A	C	C	C	A	B
Fe	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	D	Z	Z	Z
Co	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	D	Z	Z	Z	Z	Z	Z	Z
Ni	Y	Y	Y	Y	Y	B	Y	Y	Y	Y	Y	D	Y	Y	B	Y	C	B	C
Cu	A	A	A	B	D	A	C	A	D	B	A	D	A	A	D	D	C	C	D
Zn	A	A	A	A	C	C	D	C	C	B	A	C	A	A	C	D	D	C	B
Ga																			
As	X	X			X		X	X	X	X	X	C	X	X	X	D	X	X	
Rb	Y	Y	Y	Y	Y	A	Y	B	Y	Y	Y	B	Y	Y	Y	D	D	C	Y
Sr				D												D	D		
Y																			
Mo																			
Cd	Y	B	Y	Y	Y	Y	Y	Y	D	Y	Y	B	Y	Y	Y	Y	C	Y	Y
Sb	Y	Y	Y	C	Y	Y	Y	Y	Y	Y	Y	B	Y	Y	Y	C	C	C	Y
Te																			
Cs	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	D	D	Y	Y
Ba																			
La	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	D	D	C	Y	Y
Tl																			
Pb	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	C	A	B
Bi																			
Th	Y	Y	Y	Y	Y	Y	Y	Y	Y	D	Y	Y	Y	Y	Y	D	Y	Y	Y
U																			

4.3.1 Polytetrafluoroethylene (PTFE) membrane filters

PTFE filters generally showed low blank values for most elements determined. The detection limit for these elements are controlled by the sensitivity of ICP-MS.

The Cr level was however generally high for most PTFE filters, with blank values ranging from 7 to 85 ng, and standard deviations of 1-10 ng Cr per filter. To achieve low detection limits for Cr the choice of filter material is critical. The results in this study indicate that Gelman TF-1000 is the best PTFE filter for measurements at remote stations.

Attention should also be paid to the Sr level in Nuclepore fn-memb. This filter type showed a mean value of 200 ng Sr and a standard deviation of 12 ng Sr per filter, and is not suitable for measurements at remote stations. The other filters analysed had blank values near the detection limit for ICP-MS (0.1 ng Sr).

4.3.2 Membrane filters of other materials

These filter types frequently show high blank values for certain elements, e.g. Na, Cr, Cu, Zn, whereas other elements may be present at similarly low levels as in PTFE filters.

The Na levels were measured to <500-15000 ng, and the filters showed standard deviations up to 3000 ng Na per filter. The Nuclepore polycarbonate filters exhibited the lowest blank values. Filters such as Millipore MF, Nuclepore membra-fil, Gelman DM-metricel and Gelman Supor-800 were found to have high blank values of Na (6700-12000 ng), but all of them showed low standard deviations (160-490 ng per filter).

The Cr levels ranged from 29 to 460 ng and the standard deviations varied between 4 and 170 ng per filter. These membrane filters had higher Cr-levels than PTFE filters. None of the filters are satisfactory for determination of Cr in remote areas.

Gelman versapor and Nuclepore PVC showed standard deviations of respectively 0.2 and 0.4 ng Co per filter, and are least suited of the analysed filters for measurements of Co.

Gelman versapor also had a standard deviation of 12 ng Ni per filter, and is not very suited for measurements of Ni in remote areas.

All filters showed blank values for Cu ranging from <4 to 320 ng per filter, with the exception of Gelman versapor with a blank value as high as 2400 ng. The filters showed standard deviations up to 190 ng Cu per filter. The polycarbonate filters from Nuclepore had the lowest blank values (<4 ng Cu). Millipore MF showed a mean value of 24 ng Cu, but a standard deviation as low as 1 ng Cu per filter. Gelman GN-4 , Gelman DM-metricel, Gelman versapor and Nuclepore PVC showed standard deviations of respectively 19, 41, 190 and 150 ng Cu per filter, and the filters are not very suited for measurements at background stations.

These membrane filters had blank values from 9 to 330 ng Zn and standard deviations between 2.8 and 65 ng per filter. The polycarbonate filters from Nuclepore had the lowest blank values and the lowest standard deviations.

Gelman DM metricel and Gelman versapor showed standard deviations of 0.7 ng and 7 ng Mo per filter. The same filters had standard deviations of 20 and 1 ng Cd per filter, and are least suited from the analysed filters for measurements of Mo and Cd.

Nuclepore PVC showed a standard deviation of 0.8 ng La per filter, and is not very well suited for determination of La at background stations.

Attention may also be paid to the Th level in Gelman GLA-5000, of 0.3 ng with a standard deviation of 0.1 ng Th per filter.

4.3.3 Fiber filters

All glass fiber filters had very high blank values of alkali metals (Li, Na, Rb, Cs), alkali earth metals (Sr, Ba) and the group IIIA elements (B, Tl). They also showed high levels of Cr, Cu and Zn. None of the elements above are satisfactorily measured in background areas with the use of glass fiber filters.

The quartz fiber filter showed high blank values of some elements, e.g. B, Na, Mg, Cr, Zn, Sr, Mo and Ba whereas other elements were in most cases at similar low levels as in PTFE filters. The filter showed standard deviations of respectively 33, 1.5 and 9.4 ng per filter for Cr, Mo and Ba, and are therefore not well suited for determination of these elements at remote sites.

Whatman 40 exhibited a very high blank value of Cu (110 ng) and a standard deviation of 45 ng, but generally very low levels of other elements. The mean value and standard deviation for Cr (respectively 7 and 0.6 ng per filter) are for example as low as for the best PTFE filter.

5 CONCLUSION

The results show that the variation in the element contents of the analysed filters is quite large. Glass fiber filters have high blank values of a number of elements, whereas PTFE filters generally are the cleanest. However, most filter types have high blank values of one or more elements of interest in aerosol measurements. This knowledge is a prerequisite for selecting the filter best suited for aerosol experiments.

It is also necessary to have the sampling volume in mind, because a higher sampling volume will give a lower detection limit.

The results of this work only provide a rough estimate of the variations in element contents of different filter types. It is always advisable to measure the blank values of the elements of interest in the filter materials to be used for sampling in each case. Based on the blank values obtained, the mean values and standard deviations can be calculated so that the detection limit for use can be estimated in each case. Only filters from one batch of each filter type were analysed in this work. Different batches of the same filter type are likely to give different results, and it will always be necessary to measure analytical blanks. Nevertheless the present data may provide a useful guide as to what filter types may be acceptable at the present state of the art in trace element studies in air.

5 REFERENCES

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APPENDIX

Data for each filter type

mean	:	mean value (ng per filter)
minimum	:	lowest measured value (ng per filter)
maximum	:	highest measured value (ng per filter)
std.dev.	:	standard deviation (ng per filter)
rel.std.dev.	:	relative standard deviation (%)
N	:	number of measured filters
#<d.l.	:	number of measurements below the detection limit for ICP-MS.

1

Gelman TF-1000 (PTFE) (66155)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	2	0.6	-	10	3
Be	< 1	< 1	< 1	-	-	10	10
B	< 10	< 10	15	4.0	-	10	5
Na	< 500	< 500	< 500	-	-	10	10
Mg	28	< 20	120	33	118	10	6
V	< 1	< 1	2	0.3	-	10	0
Cr	7	6	8	1.0	14	10	0
Mn	< 2	< 2	< 2	-	-	10	0
Fe	< 1 000	< 1 000	< 1 000	-	-	10	10
Co	< 0.5	< 0.5	< 0.5	-	-	10	10
Ni	< 5	< 5	< 5	-	-	10	10
Cu	< 4	< 4	< 4	-	-	10	10
Zn	< 3	< 3	7	1.8	-	10	5
Ga	< 1	< 1	< 1	-	-	10	10
As	< 5	< 5	< 5	-	-	10	10
Rb	< 0.5	< 0.5	0.9	0.2	-	10	7
Sr	< 0.1	< 0.1	0.3	0.1	-	10	7
Y	< 0.2	< 0.2	< 0.2	-	-	10	10
Mo	< 1	< 1	< 1	-	-	10	10
Cd	< 1	< 1	3	0.7	-	10	7
Sb	< 0.5	< 0.5	< 0.5	-	-	10	10
Te	< 10	< 10	< 10	-	-	10	10
Cs	< 0.3	< 0.3	< 0.3	-	-	10	10
Ba	3	0.5	16	4.4	147	10	0
La	< 0.3	< 0.3	< 0.3	-	-	10	10
Tl	0.8	< 0.2	2	0.8	100	10	3
Pb	< 1	< 1	5	1.3	-	10	9
Bi	< 0.2	< 0.2	< 0.2	-	-	10	10
Th	< 0.1	< 0.1	< 0.1	-	-	10	10
U	< 0.1	< 0.1	< 0.1	-	-	10	10

2
Gelman zefluor (PTFE) (P5PJ047)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	< 10	< 10	< 10	-	-	11	11
Na	< 500	< 500	< 500	-	-	11	11
Mg	180	41	530	140	78	11	0
V	< 1	< 1	< 1	-	-	11	11
Cr	35	23	57	10	29	11	0
Mn	< 2	< 2	< 2	-	-	11	11
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	< 5	-	-	11	11
Cu	< 4	< 4	< 4	-	-	11	11
Zn	< 3	< 3	10	3.0	-	11	6
Ga	< 1	< 1	< 1	-	-	11	11
As	< 5	< 5	< 5	-	-	11	11
Rb	< 0.5	< 0.5	< 0.5	-	-	11	11
Sr	0.3	< 0.1	0.6	0.2	67	11	3
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	2	0.7	-	11	4
Cd	< 1	< 1	2	0.8	-	11	3
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	2	< 1	6	2.0	-	11	3
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	100	11	11
Pb	< 1	< 1	8	2.4	-	11	8
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	-	-	-	-	-	0	-

3
Millipore fluoropore (FALP 047 00)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	< 10	< 10	< 10	-	-	11	11
Na	< 500	< 500	< 500	-	-	11	11
Mg	140	60	220	56	40	11	0
V	< 1	< 1	< 1	-	-	11	11
Cr	21	15	34	7	33	11	0
Mn	< 2	< 2	< 2	-	-	11	11
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	< 5	-	-	11	11
Cu	< 4	< 4	< 4	-	-	11	11
Zn	7	4	11	2.3	33	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	-	-	-	-	-	0	-
Rb	< 0.5	< 0.5	< 0.5	-	-	11	11
Sr	0.2	0.2	0.3	0.1	50	0	-
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	2	1	3	0.5	25	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	< 1	< 1	< 1	-	-	11	11
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

4
Nuclepore fn-memb (131110)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	< 10	< 10	< 10	-	-	11	11
Na	< 500	< 500	< 500	-	-	11	11
Mg	300	190	440	90	30	11	0
V	< 1	< 1	< 1	-	-	11	11
Cr	85	70	95	7	8.2	11	0
Mn	< 2	1	4	1.0	-	11	0
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	< 5	-	-	11	11
Cu	7	< 4	13	3.4	49	11	1
Zn	18	14	28	4	22	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	-	-	-	-	-	0	-
Rb	< 0.5	< 0.5	< 0.5	-	-	11	11
Sr	200	190	220	12	6.0	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	3	0.6	-	11	8
Sb	3	2	4	0.4	13	11	0
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	4	3	7	1.7	43	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	< 1	< 1	4	1.1	-	11	7
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

5
Gelman GN-4 (64679)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	< 10	< 10	< 10	-	-	11	11
Na	15 000	14 000	16 000	980	6.5	11	0
Mg	130	23	270	98	75	11	0
V	< 1	< 1	< 1	-	-	11	11
Cr	290	230	330	26	9.0	11	0
Mn	< 2	< 2	3	0.6	-	11	5
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	< 5	-	-	11	11
Cu	19	8	64	19	55	11	0
Zn	31	21	80	17	100	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	< 5	< 5	< 5	-	-	10	10
Rb	< 0.5	< 0.5	< 0.5	-	-	11	11
Sr	0.8	0.6	1	0.2	25	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	< 1	< 1	< 1	-	-	11	11
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	< 1	< 1	< 1	-	-	11	11
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

6
Millipore MF (AAWP 047 00)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	16	15	18	1	6.3	11	0
Na	6 700	6 500	7 100	160	2.4	11	0
Mg	200	160	260	35	18	11	0
V	< 1	< 1	2	0.3	-	11	1
Cr	51	43	58	4.0	-	11	0
Mn	3	2	3	0.4	7.8	11	0
Fe	< 1 000	< 1 000	< 1 000	-	13	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	8	1.3	-	11	6
Cu	24	23	27	1	-	11	0
Zn	330	300	360	17	4.2	11	0
Ga	< 1	< 1	< 1	-	5.3	11	11
As	-	-	-	-	-	0	-
Rb	1	1	2	0.1	10	11	0
Sr	2	2	2	0.2	10	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	4	3	6	0.7	18	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	7	5	11	2.0	29	11	0
Bi	< 0.2	< 0.2	0.9	-	-	11	7
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

7
Nuclepore membra-fil (141109)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	3	0.8	-	10	9
Be	< 1	< 1	< 1	-	-	11	10
B	< 10	< 10	< 10	-	-	10	10
Na	9 700	9 600	10 000	170	1.8	11	0
Mg	310	110	1 000	280	90	11	0
V	< 1	< 1	< 1	-	-	11	11
Cr	320	260	400	42	13	11	0
Mn	13	12	14	1	7.7	11	0
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	< 5	-	-	11	11
Cu	57	51	67	4	7.0	11	0
Zn	160	130	350	65	41	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	< 5	< 5	< 5	-	-	11	11
Rb	< 0.5	< 0.5	< 0.5	-	-	11	11
Sr	3	2	3	0.2	6.7	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	6	5	9	1.2	20	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	< 1	< 1	< 1	-	-	11	11
Bi	< 0.2	< 0.2	< 0.3	0.1	-	11	7
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

8
Whatman WCN (7190 004)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	18	13	24	3	17	11	0
Na	3 000	2 600	3 400	250	8.3	11	0
Mg	650	450	1 300	240	37	11	0
V	< 1	< 1	< 1	-	-	11	11
Cr	300	180	490	88	29	11	0
Mn	< 2	< 2	< 2	-	-	11	11
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	< 5	-	-	11	11
Cu	5	< 4	9	1.6	32	11	1
Zn	32	19	78	17	53	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	< 5	< 5	7	1.3	-	11	10
Rb	1	1	2	0.2	20	11	0
Sr	14	11	17	2	14	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	4	3	8	1.2	30	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	0.4	0.2	0.6	0.1	25	11	0
Pb	3	2	11	2.8	93	11	0
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

9
Gelman DM-metricel (vinyl/acryl) (64502)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#< d.l.
Li	< 1	< 1	2	0.6	-	14	10
Be	< 1	< 1	3	0.8	-	14	8
B	< 10	< 10	< 10	-	-	14	14
Na	6 700	6 200	7 100	240	3.6	14	0
Mg	1 600	1 500	1 800	80	5	14	0
V	< 1	< 1	< 1	-	-	14	14
Cr	190	170	230	16	8.4	14	0
Mn	3	2	4	0.5	17	14	0
Fe	< 1 000	< 1 000	< 1 000	-	-	14	14
Co	< 0.5	< 0.5	< 0.5	-	-	14	14
Ni	< 5	< 5	< 5	-	-	14	14
Cu	59	14	150	41	69	14	0
Zn	45	13	120	28	62	14	0
Ga	< 1	< 1	< 1	-	-	14	14
As	< 5	< 5	< 5	-	-	14	14
Rb	< 0.5	< 0.5	0.6	0.1	-	14	11
Sr	16	15	17	1	6.3	14	0
Y	< 0.2	< 0.2	< 0.2	-	-	14	14
Mo	< 1	< 1	2	0.7	-	14	13
Cd	16	< 1	76	20	125	14	3
Sb	< 0.5	< 0.5	< 0.5	-	-	14	14
Te	< 10	< 10	< 10	-	-	14	14
Cs	< 0.3	< 0.3	< 0.3	-	-	14	14
Ba	10	9	13	1.2	12	14	0
La	< 0.3	< 0.3	< 0.3	-	-	14	11
Tl	< 0.2	< 0.2	< 0.2	-	-	14	14
Pb	2	1	6	1.6	80	14	0
Bi	< 0.2	< 0.2	< 0.2	-	-	14	14
Th	< 0.1	< 0.1	< 0.1	-	-	14	14
U	< 0.1	< 0.1	< 0.1	-	-	14	14

10
Gelman GLA-5000 (PVC) (66468)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	10	10
Be	< 1	< 1	< 1	-	-	10	10
B	-	-	-	-	-	0	-
Na	11 000	9 000	15 000	2 000	18	10	0
Mg	64	< 20	200	71	11	10	6
V	2	1	3	0.5	43	10	0
Cr	91	15	150	39	-	10	0
Mn	3	< 2	4	0.9	30	10	1
Fe	< 1 000	< 1 000	< 1 000	-	-	10	10
Co	< 0.5	< 0.5	< 0.5	-	-	10	10
Ni	< 5	< 5	< 5	-	-	10	10
Cu	5	< 4	10	2.8	56	10	5
Zn	32	24	43	7	22	10	0
Ga	< 1	< 1	< 1	-	-	10	10
As	< 5	< 5	< 5	-	-	10	10
Rb	< 0.5	< 0.5	< 0.5	-	-	10	10
Sr	2	1	3	0.4	20	10	0
Y	< 0.2	< 0.2	< 0.2	-	-	10	10
Mo	< 1	< 1	< 1	-	-	10	10
Cd	< 1	< 1	2	0.5	-	10	6
Sb	< 0.5	< 0.5	< 0.5	-	-	10	10
Te	< 10	< 10	13	3.1	-	10	8
Cs	< 0.3	< 0.3	< 0.3	-	-	10	10
Ba	< 1	< 1	< 1	-	-	10	10
La	< 0.3	< 0.3	< 0.3	-	-	10	10
Tl	< 0.2	< 0.2	< 0.2	-	-	10	10
Pb	< 1	< 1	< 1	-	-	10	10
Bi	< 0.2	< 0.2	< 0.2	-	-	10	10
Th	0.3	0.1	0.4	0.1	33	10	0
U	< 0.1	< 0.1	< 0.2	0.05	-	10	2

11
Gelman Supor-800 (polysulfone) (60110)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	< 10	< 10	< 10	-	-	11	11
Na	12 000	10 000	12 000	490	4.1	11	0
Mg	1 200	900	2 000	360	30	11	0
V	< 1	< 1	< 1	-	-	11	11
Cr	360	320	450	40	11	11	0
Mn	5	4	5	0.5	10	11	0
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	< 5	-	-	11	11
Cu	6	4	7	1.1	18	11	0
Zn	21	16	33	5	24	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	< 5	< 5	< 5	-	-	11	11
Rb	< 0.5	< 0.5	0.7	0.2	-	11	0
Sr	3	2	3	0.2	67	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	3	2	5	0.8	27	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	3	2	4	0.4	13	11	0
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

12
Gelman Versapor (acryl/nylon) (46 00000)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	< 10	< 10	< 10	-	-	11	11
Na	5 800	5 000	7 600	980	17	11	0
Mg	1 100	820	1 800	360	33	11	0
V	41	34	46	4	9.8	11	0
Cr	290	250	350	45	16	11	0
Mn	8	6	12	2.0	25	11	0
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	0.7	0.5	1	0.2	29	11	0
Ni	11	< 2	40	12	109	11	2
Cu	2 400	2 100	2 700	190	7.9	11	0
Zn	77	61	97	15	19	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	10	6	12	2.3	23	11	0
Rb	< 0.5	< 0.5	0.9	0.2	-	11	4
Sr	7	7	10	1.4	20	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	50	37	58	7	14	11	0
Cd	< 1	< 1	4	1.0	-	11	4
Sb	< 0.5	< 0.5	0.9	0.3	-	11	4
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	5	3	9	2.1	42	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	4	3	4	0.3	7.5	11	0
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

13
Nuclepore pc (111109)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	< 10	< 10	< 10	-	-	11	11
Na	< 500	< 500	< 500	-	-	11	11
Mg	80	41	260	63	79	11	0
V	< 1	< 1	< 1	-	-	11	11
Cr	460	230	730	170	37	11	0
Mn	< 2	< 2	< 2	-	-	11	11
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	< 5	< 5	< 5	-	-	11	11
Cu	< 4	< 4	< 4	-	-	11	11
Zn	13	8	18	2.8	22	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	< 5	< 5	< 5	-	-	11	11
Rb	< 0.5	< 0.5	< 0.5	-	-	11	11
Sr	0.3	0.2	0.6	0.1	33	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	2	1	9	2.5	125	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	< 1	< 1	9	2.5	-	11	2
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

14
Nuclepore pc/AP (111132)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	10	10
Be	< 1	< 1	< 1	-	-	10	10
B	< 10	< 10	< 10	-	-	10	10
Na	< 500	< 500	< 500	-	-	10	10
Mg	230	55	720	220	96	10	0
V	< 1	< 1	< 1	-	-	10	10
Cr	130	120	160	14	11	10	0
Mn	< 2	< 2	< 2	-	-	10	10
Fe	< 1 000	< 1 000	< 1 000	-	-	10	10
Co	< 0.5	< 0.5	< 0.5	-	-	10	10
Ni	< 5	< 5	< 5	-	-	10	10
Cu	< 4	< 4	5	1.1	-	10	8
Zn	9	5	20	4.8	53	10	0
Ga	< 1	< 1	< 1	-	-	10	10
As	< 5	< 5	< 5	-	-	10	10
Rb	< 0.5	< 0.5	< 0.5	-	-	10	10
Sr	0.3	0.1	0.6	0.2	67	10	1
Y	< 0.2	< 0.2	< 0.2	-	-	10	10
Mo	< 1	< 1	< 1	-	-	10	10
Cd	< 1	< 1	< 1	-	-	10	10
Sb	< 0.5	< 0.5	< 0.5	-	-	10	10
Te	< 10	< 10	< 10	-	-	10	10
Cs	< 0.3	< 0.3	< 0.3	-	-	10	10
Ba	< 1	< 1	< 1	-	-	10	10
La	< 0.3	< 0.3	< 0.3	-	-	10	10
Tl	< 0.2	< 0.2	< 0.2	-	-	10	10
Pb	< 1	< 1	< 1	-	-	10	10
Bi	< 0.2	< 0.2	0.3	0.1	-	10	9
Th	< 0.1	< 0.1	< 0.1	-	-	10	10
U	< 0.1	< 0.1	< 0.1	-	-	10	10

15
Nuclepore pvc (361550)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	< 10	< 10	< 10	-	-	11	11
Na	3 400	1 300	13 000	3 000	88	11	0
Mg	420	190	810	210	50	11	0
V	2	< 1	3	0.7	35	11	1
Cr	29	21	39	5	17	11	0
Mn	24	13	48	10	42	11	0
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	1	0.4	-	11	9
Ni	< 5	< 5	13	3.0	-	11	10
Cu	320	150	560	150	47	11	0
Zn	73	27	160	37	51	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	< 5	< 5	< 5	-	-	11	11
Rb	< 0.5	< 0.5	< 0.5	-	-	11	11
Sr	10	6	16	3.2	32	11	0
Y	< 0.2	< 0.2	0.4	0.1	-	11	3
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	6	4	9	2	33	11	0
La	0.9	< 0.3	3	0.8	89	11	2
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	23	12	42	8	35	11	0
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	0.3	0.1	-	11	5

16
Gelman A/E (glass) (61631)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	24	15	40	6	25	10	0
Be	3	< 1	12	3.6	120	10	1
B	5 100	3 800	6 700	860	17	10	0
Na	80 000	66 000	96 000	8 000	10	10	0
Mg	940	690	1 100	140	15	10	0
V	3	2	6	1.4	47	10	0
Cr	71	55	94	12	17	10	0
Mn	19	14	33	5	26	10	0
Fe	2 000	1 600	3 700	650	33	10	0
Co	< 0.5	< 0.5	2	0.5	-	10	8
Ni	< 5	< 5	< 5	-	-	10	10
Cu	35	14	97	23	66	10	0
Zn	11 000	8 000	13 000	1 600	15	10	0
Ga	-	-	-	-	-	0	-
As	8	< 5	40	11	138	10	7
Rb	320	260	350	26	8.1	10	0
Sr	250	180	270	28	11	10	0
Y	0.5	< 0.2	3	0.7	140	10	2
Mo	2	< 1	10	2.5	125	10	1
Cd	< 1	< 1	6	1.7	-	10	8
Sb	2	0.7	4	1.0	50	10	0
Te	< 10	< 10	< 10	-	-	10	10
Cs	16	13	22	2	13	10	0
Ba	15 000	11 000	17 000	1 800	12	10	0
La	1	0.8	3	0.5	50	10	0
Tl	1	0.9	2	0.4	40	10	0
Pb	62	50	74	6	9.7	10	0
Bi	< 0.2	< 0.2	1	0.3	-	10	9
Th	0.3	0.1	1.3	0.3	100	10	0
U	-	-	-	-	-	0	-

17
Whatman GF/A (glass) (1820 037)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	11	8	12	1.1	10	11	0
Be	< 1	< 1	2	0.5	-	11	6
B	21 000	18 000	24 000	2 300	11	11	0
Na	100 000	95 000	110 000	5 800	5.8	11	0
Mg	2 400	1 900	2 600	210	8.8	11	0
V	8	7	9	1.0	13	11	0
Cr	65	45	71	6	9.2	11	0
Mn	12	7	23	4.2	35	11	0
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	13	9	15	2.1	16	11	0
Cu	50	34	74	15	30	11	0
Zn	36 000	27 000	39 000	3 200	8.9	11	0
Ga	-	-	-	-	-	0	-
As	< 5	< 5	< 5	-	-	11	11
Rb	180	160	190	10	5.6	11	0
Sr	900	710	970	68	7.6	11	0
Y	0.5	< 0.2	0.6	0.2	40	11	1
Mo	< 1	< 1	< 1	-	-	11	11
Cd	2	< 1	4	1.1	55	11	3
Sb	3	2	4	0.6	20	11	0
Te	< 10	< 10	< 10	-	-	11	11
Cs	6	5	6	0.5	8.3	11	0
Ba	44 000	36 000	47 000	3 100	7.0	11	0
La	2	1	2	0.2	10	11	0
Tl	2	1	2	0.2	10	11	0
Pb	55	39	94	16	29	11	0
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	0.2	0.05	-	11	2
U	< 0.1	< 0.1	0.2	0.05	-	11	4

18
Whatman QM-A (quarts) (1851 047)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	9	9
Be	< 1	< 1	< 1	-	-	9	9
B	160	130	200	19	12	9	0
Na	37 000	34 000	38 000	1 200	3.2	9	0
Mg	1 800	1 500	2 200	250	14	9	0
V	< 1	< 1	< 1	-	-	9	9
Cr	110	69	160	33	30	9	0
Mn	4	4	6	1.0	25	9	0
Fe	< 1 000	< 1 000	< 1 000	-	-	9	9
Co	< 0.5	< 0.5	< 0.5	-	-	9	9
Ni	< 5	< 5	6	1.3	-	9	3
Cu	11	7	24	5	45	9	0
Zn	68	33	110	29	43	9	0
Ga	< 1	< 1	< 1	-	-	9	9
As	< 5	< 5	< 5	-	-	9	9
Rb	0.8	< 0.5	2	0.3	38	9	1
Sr	18	15	20	1.5	8.3	9	0
Y	0.3	< 0.2	0.5	0.1	33	9	2
Mo	6	5	10	1.5	25	9	0
Cd	< 1	< 1	< 1	-	-	9	9
Sb	1	0.6	2	0.3	30	9	0
Te	< 10	< 10	< 10	-	-	9	9
Cs	< 0.3	< 0.3	< 0.3	-	-	9	9
Ba	30	20	49	9.4	31	9	0
La	< 0.3	< 0.3	< 0.3	-	-	9	9
Tl	< 0.2	< 0.2	< 0.2	-	-	9	9
Pb	9	5	21	4.8	53	9	0
Bi	0.6	< 0.2	2	0.7	117	9	5
Th	< 0.1	< 0.1	< 0.1	-	-	9	9
U	< 0.1	< 0.1	< 0.1	-	-	9	9

19
Whatman W 40 (cellulose) (1440 047)

	Mean	Minimum	Maximum	Std. dev.	Rel.std. dev.(%)	N	#<d.l.
Li	< 1	< 1	< 1	-	-	11	11
Be	< 1	< 1	< 1	-	-	11	11
B	32	29	34	2	6.3	11	0
Na	4 000	2 000	5 200	760	19	11	0
Mg	390	280	600	92	24	11	0
V	2	1	2	0.3	15	11	0
Cr	7	6	8	0.6	8.6	11	0
Mn	< 2	< 2	6	1.5	-	11	5
Fe	< 1 000	< 1 000	< 1 000	-	-	11	11
Co	< 0.5	< 0.5	< 0.5	-	-	11	11
Ni	10	9	12	1.1	11	11	0
Cu	110	78	240	45	41	11	0
Zn	22	13	52	12	55	11	0
Ga	< 1	< 1	< 1	-	-	11	11
As	-	-	-	-	-	0	-
Rb	< 0.5	< 0.5	< 0.5	-	-	11	11
Sr	10	8	14	2.1	21	11	0
Y	< 0.2	< 0.2	< 0.2	-	-	11	11
Mo	< 1	< 1	< 1	-	-	11	11
Cd	< 1	< 1	< 1	-	-	11	11
Sb	< 0.5	< 0.5	< 0.5	-	-	11	11
Te	< 10	< 10	< 10	-	-	11	11
Cs	< 0.3	< 0.3	< 0.3	-	-	11	11
Ba	16	9	28	6	38	11	0
La	< 0.3	< 0.3	< 0.3	-	-	11	11
Tl	< 0.2	< 0.2	< 0.2	-	-	11	11
Pb	8	5	25	6	75	11	0
Bi	< 0.2	< 0.2	< 0.2	-	-	11	11
Th	< 0.1	< 0.1	< 0.1	-	-	11	11
U	< 0.1	< 0.1	< 0.1	-	-	11	11

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TITTEL Blank Values of 30 Elements in 19 Filter Materials Determined by ICP-MS		PROSJEKTLEDER T. Berg	
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STIKKORD

Filter Materials	Blank Values	ICP-MS

REFERAT

Blindverdier av 30 elementer i 19 forskjellige filter materialer fra Gelman, Millipore, Nuclepore og Whatman har blitt studert. Filtrene ble ekstrahert i 0.2 M HNO_3 , og analysert vha ICP-MS. Det ble funnet store forskjeller i blindverdier mellom forskjellige filter materialer. Glass fiber filter hadde høye blindverdier for mange elementer, mens PTFE filter stort sett var renest. De fleste filter typene hadde imidlertid høge blindverdier for et eller flere elementer av interesse i aerosol målinger.

TITLE

Blank Values of 30 Elements in 19 Filter Materials determined by ICP-MS

ABSTRACT

The blank values of 30 elements in 19 different filter types from Gelman, Millipore, Nuclepore and Whatman have been compared. The filter media were extracted with dilute nitric acid and the element contents determined by ICP-MS. Large differences in blank values were observed between different filter materials. Glass fiber filters showed high blank values for a number of elements, whereas PTFE filters generally were the cleanest. However, most filter types showed high blank values of one or more elements of interest in aerosol measurements.

* Kategorier:		
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