Statens
arbeidsmiljøinstitutt

Title: Proficiency Testing for Measurement of Elements in Workplace Air Filters. Round 7.

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Date: 12.10.98 **ISSN:** 0801-7794 **Series:** HD-1094/98/FOU

Summary:

In this proficiency testing programme one English, two Finnish, two Danish and five Norwegian laboratories have participated.

Realistic work-room air filters and reference filters were distributed to the participants in August 1998 with a deadline for replies of 18th of September 1998.

The laboratories were asked to carry out measurements of a number of occupational important elements listed in the enclosed protocol (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sn, Zn).

Five out of the ten laboratories completed the analytical protocol with a performance complying with the assessment criteria.

Stikkord: Interkalibrering
Grunnstoffbestemmelse
Arbeidsatmosfære

Key words: Proficiency testing
Determination of elements
Workroom air filters

CONTENTS

SUMMARY

The purpose of this proficiency testing programme is to investigate the performance of methods used for routine analyses by commercial, public and industrial laboratories.

Welding fume filters (Series U) and synthetically produced reference filters (Series B-2) were distributed to the participating laboratories in August 1998.

In order to determine the "true" quantities of elements on the filters, randomly selected parallel filters from each filter series were analysed at the National Institute of Occupational Health in Oslo. The reference values for Series U (welding fume) were based on the results using ICP-AES. The reference values for Series B-2 (reference filters) were calculated and the theoretical values verified by chemical analyses.

In this round of the proficiency testing programme ten laboratories have participated: one English, two Finnish, two Danish and five Norwegian. Each was asked to determine a total of ten elements in two filter matrices (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sn, Zn). Five out of the ten laboratories completed the analytical protocol with a performance complying with the assessment criteria.

The inter-laboratory variance for the individual elements after rejection of outliers shows improved agreement among the participants compared to the results in Round 6.

ABBREVIATIONS

EAAS:	Electrothermal Atomic Absorption Spectrometry
FAAS:	Flame Atomic Absorption Spectrometry
ICP-AES:	Inductively Coupled Plasma Atomic Emission Spectrometry
ICP-MS:	Inductively Coupled Plasma Mass Spectrometry
RSD:	Relative Standard Deviation
SD:	Standard Deviation

1. INTRODUCTION

The National Institute of Occupational Health in Oslo is the national reference laboratory for work environment analyses in Norway, as well as a regional laboratory for the Labour Inspectorates (1. - 4. district). As a national reference laboratory one of the objectives is to carry out proficiency testing programmes for work environment analyses in commercial, public and industrial laboratories.

There is no official approval scheme for laboratories which offer work environment analyses in Norway, but the Governmental Labour Inspectorate requests all laboratories to participate in the proficiency testing programmes organised by the National Institute of Occupational Health. Participation is voluntary, and the laboratories are informed in advance that the results will be published with identification of the participants. The purpose of this proficiency testing programme is to investigate the performance of methods used for routine analyses. The laboratories were therefore requested to include the samples in their normal analytical routine.

Samples were distributed August 1998, with a deadline for replies of 18th of September. Each participant received duplicates of work-room air filters (Series U), reference filters spiked with known quantities of selected elements (Series B-2) and blank filters. The laboratories were asked to carry out measurements of the elements listed in the enclosed protocol.

2. PARTICIPATING LABORATORIES

Lab.no	Name, address	Short Form
1	Arbeidstilsynet 6. distrikt, laboratoriet P.O.Box 639 N-4601 Kristiansand, Norway	A. Kr.sand
2	Falconbridge Nikkelverk A/S, Hovedlaboratoriet P.O.Box 457 N-4601 Kristiansand, Norway	Falconbridge
3	Health and Safety Laboratory Broad Lane UK-Sheffield S3 7HQ, United Kingdom	HSL
4	Kuopio Region Institut för Arbetshygien P.O.Box 93 FIN-70701 Kuopio, Finland	Kuopio
5	Miljø-Kemi, Dansk Miljøsenter A/S Smedeskovvej 38 DK-8464 Galten, Denmark	Miljø-Kemi
6	National Institute of Occupational Health Lersø Parkallè 105 DK-2100 København Ø, Denmark	NIOH

7	Oulun Aluetyöterveyslaitos, Kemian laboratorio Aapistie 1 FIN-90220 Oulo, Finland	Oulun
8	Sero AS, Avd. Norsk Analyse Center P.O.Box 24 N-1361 Billingstad, Norway	Sero
9	Tinfos Jernverks as, Øye Smelteverk P.O.Box 246 N-4481 Kvinesdal	Tinfos
10	West Lab AS Oljeveien 2 N-4056 Tananger, Norway	West Lab

3. SAMPLING

The multi-channel sampler unit used for the collection of replicate filter samples of welding fumes was developed at the National Institute of Occupational Health in Oslo.

To ensure constant flowrates through the filters during the sampling period each position is equipped with a critical orifice. The flowrate through each filter was measured at the start and stop of sampling using a high precision rotameter.

The parallel sampler was designed for use with 25 mm plastic filter holders (Costar - Nuclepore art.no. N-800932) with an extended connecting piece. Since these filter holders are no longer available the 25 mm plastic filter holders used in this round (Millipore art.no. M000 025 A0) were mounted to the parallel sampler using external connecting pieces. Particulate matter was collected on 0,8 µm cellulose ester membrane filters (Millipore art.no. AAWP 025 00).

In order to obtain homogeneous deposition on the filters the filter holders are open-faced. This is of particular importance for X-ray fluorescence spectrometry for the direct measurement of the analytes.

Welding fumes were generated in the workshop at the National Institute of Occupational Health in Oslo.

4. REFERENCE FILTERS

Reference filters were prepared by spiking 37 mm cellulose ester membrane filters (Millipore art.no. AAWP 037 00) with an aqueous solution containing elements with concentrations gravimetrically traceable to ultrapure metals or stoichiometrically well defined oxides. The amounts correspond to approximately half of the threshold limit values of contaminations in workroom atmospheres (provided that the simulated filter

has been exposed to one cubic meter of air). The reference values are based on a gravimetric procedure, i.e. weight per volume composition of the primary reference material dissolved in high purity sub-distilled acids.

5. ANALYTICAL CONDITIONS

The sample preparation and analytical methods used by the participants are presented in the following table:

Laboratory	Sample Preparation	Sample-volume	Analytical Method
A. Kr.sand	Aqua regia and HF, teflon autoclave with microwave assisted digestion.	17,2 ml	ICP-AES
Falconbridge	HNO_3 and HCl, hot plate digestion.	50 ml	ICP-AES
HSL	HNO_3 /HF, teflon autoclave with microwave assisted digestion.	25 ml	ICP-AES
Kuopio	HNO_3/HCl, teflon autoclave with microwave assisted digestion.		FAAS
Miljø-Kemi	HNO_3, teflon autoclave with microwave assisted digestion.		ICP-AES
NIOH	HNO_3/HCl, hot plate digestion.		ICP-AES
Oulun	HNO_3/HCl, teflon autoclave with microwave assisted digestion.	25 ml	FAAS EAAS
Sero	HNO_3/HCl/HF, teflon autoclave, heated in laboratory oven.	25 ml	ICP-AES
Tinfos	HNO_3/HCl, teflon autoclave with microwave assisted digestion.	100 ml	FAAS
West Lab	NIOSH Method 7300.		ICP-AES

6. REFERENCE VALUES

In order to determine the "true" quantities of elements on the filters, randomly selected parallel filters from each filter series were analysed at the National Institute of Occupational Health in Oslo. Filters from both series were dissolved in 2 ml aqua regia and 0,2 ml hydrofluoric acid in teflon autoclaves with microwave assisted digestion. After cooling to room temperature all samples were diluted with ultra pure water to a volume of 25 ml.

All volumetric equipment which was used for the preparation of samples and standard solutions was volumetrically calibrated. The maximum volumetric uncertainty was 0,1 %.

All standard solutions (traceable to NIST primary certified solutions) used for instrument calibrations were matrix-matched to be as nearly as possible identical to the sample solutions in order to minimise inter-element and matrix effects.

For the measurement of all elements a simultaneous Perkin-Elmer OPTIMA 3000 inductively coupled plasma atomic emission spectrometer (ICP-AES) was used.

The reference values for Series U (welding fumes) are based on the results using ICP-AES. The results are given in Appendix 1, table 3 and 4. The filter-to-filter variation shown in table 4 (RSD %) is increased (2,2 - 2,8 %) compared to expected results (RSD < 1 %) based on earlier experiments. This may probably be a consequence of the use of the external connecting pieces for mounting the filter holder to the sampler. Small leakages may have occurred during sampling.

The spiked analyte masses of the reference filters (Series B-2) are measured by weighing. Exact reference value of individual filters are obtained by using a correction factor for each filter. The theoretical values are verified by chemical analysis. The results are given in Appendix 1, table 1 and 2.

7. ASSESSMENT CRITERIA

The National Institute of Occupational Health in Oslo has drawn up proposals for assessing analytical performance. Routine measurements of workroom air filters should comply to the following criteria:

Quantity in relation to TLV	**Requirement 1 Good accuracy**	**Requirement 2 Acceptable accuracy**
>100 %	Better than $\pm$ 5 %	Better than $\pm$ 10 %
10 %	Better than $\pm$ 10 %	Better than $\pm$ 20 %
1 %	Better than $\pm$ 25 %	Better than $\pm$ 50 %

Accuracies considered «good» or «acceptable» are dependent on the relationship between the concentration in a sample and the threshold limit value (TLV) for each individual element, expressed by the following formula:

$$\log y = 4{,}8*\exp(-2)*\log x^2 - 4{,}5*\exp(-1)*\log x + 1{,}4$$

where x is the proportion of element in sample relative to TLV (in %)
y is requirement 1 or 2 (in %)

Analyses performed at the National Institute of Occupational Health in Oslo show that filter-to-filter variation was $\leq$ 1 % (relative standard deviation) for Series B-2 and $\leq$ 2,5 % for Series U. In order to take filter homogeneity into account, two times the relative standard deviations is added.

The following limits emerge:

Requirement 1 or 2 + filter homogeneity (2 RSD)

Thus, instances of results falling outside the acceptable limits because of filter quality are rejected after applying Grafs and Hennings method for evaluation of extreme analytical results.

8. DETECTION LIMIT

With regard to samples from workroom atmospheres, detection limits for analytical procedures should reflect the threshold limit value for each element. Provided that the filter has been exposed to one cubic meter of air, the detection limit of the applied method of analysis must be no higher than 1% of the TLV.

Element	Threshold limit value, µg/m^3	Detection limit µg
Cd	20	0,2
Co	50 (fume)	0,5
Cr	500	5
Cu	100 (fume)	1
Fe	3000	30
Mn	1000 (fume)	10
Ni	100	1
Pb	50	0,5
Sn	2000	20
Zn	4000	4

9. RESULTS

The results reported by the participating laboratories are given in Appendix 1, Table 5 (Series B-2) and Table 6 (Series U).

The individual results are also presented graphically in Appendix 2.

The performances of the participating laboratories are summarised in Table 1 and 2. Results complying to Requirement 1 («good accuracy») are indicated by ●, results complying to Requirement 2 («acceptable accuracy») are indicated by ○, while results outside these two acceptance limits are indicated «not acceptable», ↙. To comply with either Requirement 1 or Requirement 2 both parallel measurements must fall within the acceptance limits.

Table 1. Summary of results: Series B-2 - Reference filters.

		Cd	Co	Cu	Ni	Pb	Sn
	Reference value, µg	**8,29**	**20,7**	**41,7**	**33,5**	**20,5**	**21,0**
1	**Arb.tils. Kr.sand**	●	●	●	●	●	●
2	**Falconbridge**	●	●	●	●	●	●
3	**HSL**	↙	○	○	○	↙	●
4	**Kuopio**	●	○	●	●	●	
5	**Miljø-Kemi**	●	●	●	●	●	●
6	**NIOH**	●			↙	●	
7	**Oulun**	●	●	●	●	○	●
8	**Sero**	●	●	●	●	●	●
9	**Tinfos**	●	●	●	●	↙	
10	**West Lab**	●	●	●	●	●	●

●: «good accuracy» ○: «acceptable accuracy» ↙: «not accepted»
«blank»: «not measured»

Table 2. Summary of results: Series U - Welding fume filters.

		Cr	Fe	Mn	Ni	Pb	Zn
	Reference value	**30,5**	**48,0**	**13,8**	**22,7**	**516**	**36,9**
1	**Arb.tils. Kr.sand**	●	●	●	●	●	●
2	**Falconbridge**	●	●	●	●	●	●
3	**HSL**	●	●	●	●	↙	●
4	**Kuopio**	↙	●	●	●	●	●
5	**Miljø-Kemi**	●	●	●	●	↙	●
6	**NIOH**	●	●	●	↙	●	●
7	**Oulun**	●	●	●	●	●	●
8	**Sero**	●	●	●	●	●	●
9	**Tinfos**	●	●	○	●	●	●
10	**West Lab**	●	●	●	●	●	●

●: «good accuracy» ○: «acceptable accuracy» ↙: «not accepted»
«blank»: «not measured»

10. DISCUSSION

In this round of the proficiency testing programme the participating laboratories were asked to determine a total of 10 elements in two filter matrices. Five out of the ten laboratories completed the analytical protocol with a performance complying with Requirement 1 or 2.

The inter-laboratory relative standard deviations after rejection of outliers range, depending on the element, varies from 3,4 to 13 % (5,5 - 22% in Round 6). In average for all elements the deviation is 7,3 % (10 % in Round 6) which shows good agreement among the participants and an improvement compared to the results in Round 6.

Quality control filters for daily use are available from the National Institute of Occupational Health, Oslo, at moderate cost. The use of these may be beneficial in further improving the quality of the laboratory measurements.

Table 3. Laboratory results for the last six proficiency testing programmes.

Round	No of laboratories	No of elements	No of measurements	● %	○ %	↙ %	Extreme values, %
0	9	15	185	65	21	14	**12**
1	14	22	652	56	24	20	**7**
2	12	13	372	70	17	10	**4**
3	18	11	285	68	18	13	**2**
4	20	11	201	36	21	23	**10**
5	15	9	199	79	8	13	**3**
6	16	10	153	78	15	7	**1,5**
7	10	10	115	88	6	7	**4**

APPENDIX 1

Table 1. ICP-AES analyses of reference filters, Series B-2.
Randomly selected filters analysed at National Institute of Occupational Health, Oslo.

Analytical wave-length in nm	Filter no. B2-366 µg	Filter no. B2-385 µg	Filter no. B2-468 µg	Filter no. B2-483 µg	Filter no. B2-968 µg	Filter no. B2-984 µg	Filter no. B2-1064 µg	Filter no. B2-1083 µg	Filter no. B2-1255 µg	Filter no. B2-1292 µg
Cd 214.438	8,42	8,32	8,35	8,26	8,28	8,18	8,31	8,27	8,24	8,25
Cd 226.502	8,41	8,32	8,40	8,27	8,29	8,21	8,27	8,28	8,26	8,27
Co 228.616	20,9	20,8	20,8	20,7	20,6	20,5	20,7	20,6	20,6	20,6
Co 230.786	20,9	20,8	20,9	20,6	20,6	20,5	20,7	20,6	20,6	20,7
Cu 221.458	44,4	43,5	43,4	42,9	42,1	41,1	40,8	42,5	40,9	41,1
Cu 224.700	44,7	43,7	43,8	43,2	42,7	41,5	41,6	42,8	41,5	41,7
Cu 324.754	44,6	43,5	43,2	42,9	42,6	41,1	41,3	43,0	41,4	41,4
Ni 231.604	33,9	33,7	33,7	33,4	33,6	33,3	33,5	33,4	33,3	33,4
Ni 232.003	33,4	33,4	33,6	33,1	33,2	33,1	33,1	33,2	33,1	33,1
Ni 341.476	33,5	33,7	33,8	33,3	33,4	33,1	33,3	33,3	33,1	33,3
Pb 220.353	20,6	20,6	20,8	20,5	20,3	20,3	20,3	20,3	20,3	20,2
Sn 189.933	22,3	21,8	22,1	21,7	21,5	20,8	21,1	21,8	21,1	21,1

Table 2. Corrected values obtained by ICP-AES and reference values, Series B-2.

	Correction factor	Cd µg	Co µg	Cu µg	Ni µg	Pb µg	Sn µg
B2-366	1,003	8,39	20,8	44,5	33,5	20,5	22,2
B2-385	0,999	8,33	20,8	43,6	33,7	20,7	21,8
B2-468	0,998	8,39	20,9	43,6	33,8	20,8	22,1
B2-483	0,998	8,29	20,7	43,1	33,3	20,5	21,7
B2-968	1,005	8,25	20,5	42,2	33,2	20,2	21,4
B2-984	0,998	8,22	20,6	41,3	33,2	20,3	20,9
B2-1064	0,995	8,33	20,8	41,5	33,4	20,4	21,2
B2-1083	1,001	8,27	20,6	42,7	33,3	20,3	21,8
B2-1255	0,998	8,27	20,6	41,4	33,3	20,3	21,1
B2-1292	1,002	8,24	20,6	41,3	33,2	20,1	21,0
Average		**8,30**	**20,7**	**42,5**	**33,4**	**20,4**	**21,5**
SD, µg		**0,06**	**0,13**	**1,14**	**0,20**	**0,21**	**0,46**
RSD %		**0,72**	**0,62**	**2,69**	**0,61**	**1,05**	**2,15**
Reference value		**8,29**	**20,7**	**41,7**	**33,5**	**20,5**	**21,0**
Recovery, %		**100,1**	**100,0**	**102,0**	**99,7**	**99,6**	**102,5**

Table 3. ICP-AES analyses of welding fume filters, Series U.
Randomly selected filters analysed at the National Institute of Occupational Health, Oslo

Analytical wave-length in nm	Filter no. U-6 µg	Filter no. U-11 µg	Filter no. U-16 µg	Filter no. U-20 µg	Filter no. U-26 µg	Filter no. U-36 µg	Filter no. U-45 µg	Filter no. U-52 µg	Filter no. U-71 µg	Filter no. U-95 µg
Cr 205.552	30,9	30,1	29,9	29,7	30,5	30,9	29,4	30,7	31,6	31,1
Cr 206.149	30,9	30,2	29,9	29,6	30,6	31,0	29,5	30,7	31,7	31,3
Cr 267.716	30,9	30,2	30,0	29,8	30,6	30,9	29,6	30,8	31,7	31,3
Cr 357.869	30,5	30,2	29,9	29,6	30,4	30,9	29,4	29,5	31,5	31,2
Fe 234.349	49,0	47,3	46,7	46,4	48,0	48,5	46,2	48,4	49,8	49,3
Fe 238.204	49,0	47,6	46,8	46,6	47,9	48,6	46,3	48,6	49,8	49,3
Mn 257.610	13,9	13,6	13,4	13,4	13,7	13,8	13,3	13,8	14,4	14,2
Mn 260.569	13,9	13,6	13,4	13,4	13,7	13,8	13,3	13,8	14,5	14,2
Mn 294.920	14,0	13,7	13,4	13,5	13,7	13,8	13,3	13,8	14,4	14,3
Ni 231.604	23,1	22,2	22,2	22,1	22,8	23,2	22,0	23,0	23,7	23,5
Ni 232.003	22,9	22,3	22,2	22,1	22,8	23,3	21,9	22,6	23,6	23,5
Ni 341.476	22,8	22,2	22,1	22,0	22,8	23,0	22,2	22,4	23,9	23,4
Pb 220.353	519	507	504	499	521	522	503	523	535	526
Zn 202.548	38,5	36,7	35,8	35,9	36,9	36,7	35,5	38,2	38,2	37,3
Zn 206.200	38,5	36,6	35,7	35,8	36,9	36,6	35,4	38,0	38,2	37,2
Zn 213.856	38,3	36,6	35,8	35,8	36,8	36,7	35,4	37,2	38,0	37,2

Table 4. Reference values, Series U - welding fume filters.

Filter no.	Cr µg	Fe µg	Mn µg	Ni µg	Pb µg	Zn µg
U-6	30,8	49,0	13,9	22,9	519	38,4
U-11	30,2	47,5	13,6	22,2	507	36,6
U-16	29,9	46,7	13,4	22,2	504	35,8
U-20	29,7	46,5	13,5	22,1	499	35,9
U-26	30,5	48,0	13,7	22,8	521	36,9
U-36	30,9	48,5	13,8	23,1	522	36,7
U-45	29,5	46,3	13,3	22,0	503	35,4
U-52	30,4	48,5	13,8	22,7	523	37,8
U-71	31,6	49,8	14,4	23,7	535	38,1
U-95	31,2	49,3	14,2	23,4	526	37,3
Reference value	**30,5**	**48,0**	**13,8**	**22,7**	**516**	**36,9**
SD	**0,68**	**1,2**	**0,36**	**0,60**	**11,8**	**1,0**
RSD, %	**2,2**	**2,6**	**2,6**	**2,6**	**2,3**	**2,8**

Table 5. Results reported by the participating laboratories, Series B-2 - Reference Filters

			Reported results						Corrected results					
Laboratory	Filter no.	Weight	Cd	Co	Cu	Ni	Pb	Sn	Cd	Co	Cu	Ni	Pb	Sn
		µg	µg	µg	µg	µg	µg	µg	µg	µg	µg	µg	µg	µg
Arb.tils. Kr.sand	B2-1351	1,000	8,43	20,8	43,4	34,1	20,5	21,3	8,43	20,8	43,4	34,1	20,5	21,3
	B2-1400	1,000	8,39	20,5	42,6	33,6	20,7	21,2	8,39	20,5	42,6	33,6	20,7	21,2
Falconbridge	B2-1370	1,001	7,74	20,9	41,9	33,7	20,4	19,5	7,73	20,9	41,9	33,7	20,4	19,5
	B2-1371	1,000	7,68	20,8	42,0	33,4	20,0	18,8	7,68	20,8	42,0	33,4	20,0	18,8
HSL	B2-1336	1,000	6,80	18,0	37,1	28,3	17,1	17,9	6,80	18,0	37,1	28,3	17,1	17,9
	B2-1337	0,999	7,05	18,6	38,1	29,0	17,6	18,5	7,06	18,6	38,1	29,0	17,6	18,5
Kuopio	B2-1368	1,000	8	23	43	33	22		8	23	43	33	22	
	B2-1369	1,001	8	21	43	33	22		8	21	43	33	22	
Miljø-Kemi	B2-1326	1,002	7,83	19,9	38,3	31,3	20,2	19,5	7,81	19,9	38,2	31,2	20,2	19,5
	B2-1327	1,003	7,90	20,0	39,0	31,4	20,6	20,1	7,88	19,9	38,9	31,3	20,5	20,0
NIOH	B2-1366	0,999	7,762			24,275 *	19,687		7,770			24,299 *	19,707	
	B2-1367	1,000	7,862			24,350 *	19,237		7,862			24,350 *	19,237	
Oulun	B2-1382	1,000	7,98	19,53	43,70	34,78	22,25	23,90	7,98	19,53	43,70	34,78	22,25	23,90
	B2-1383	1,006	7,98	19,75	43,83	35,13	22,75	25,25	7,93	19,63	43,57	34,92	22,61	25,10
Sero AS	B2-1376	1,000	8,7	20,9	43,7	34,2	20,5	21,7	8,7	20,9	43,7	34,2	20,5	21,7
	B2-1377	1,005	8,5	20,9	42,9	33,6	19,4	19,2	8,5	20,8	42,7	33,4	19,3	19,1
Tinfos	B2-1340	0,998	8	21	42	35	24		8	21	42	35	24	
	B2-1341	1,000	8	21	42	35	24		8	21	42	35	24	
West Lab	B2-1384	0,999	8,6	21	41	35	20	21	8,6	21	41	35	20	21
	B2-1385	1,001	8,7	21	41	35	21	21	8,7	21	41	35	21	21
Reference value									**8,29**	**20,7**	**41,7**	**33,5**	**20,5**	**21,0**
Average			**8,0**	**20,5**	**41,6**	**33,3**	**20,7**	**20,6**	**8,0**	**20,5**	**41,5**	**33,2**	**20,7**	**20,6**
SD, µg			**0,5**	**1,1**	**2,1**	**2,0**	**1,8**	**2,0**	**0,5**	**1,1**	**2,1**	**2,0**	**1,8**	**2,0**
RSD, %			**6,1**	**5,3**	**5,1**	**6,1**	**8,6**	**9,9**	**6,1**	**5,3**	**5,0**	**6,1**	**8,6**	**9,8**

*: Outlier, result rejected after applying Grafs and Hennings method for evaluation of extreme analytical results.

A significance level of 95 % was used.

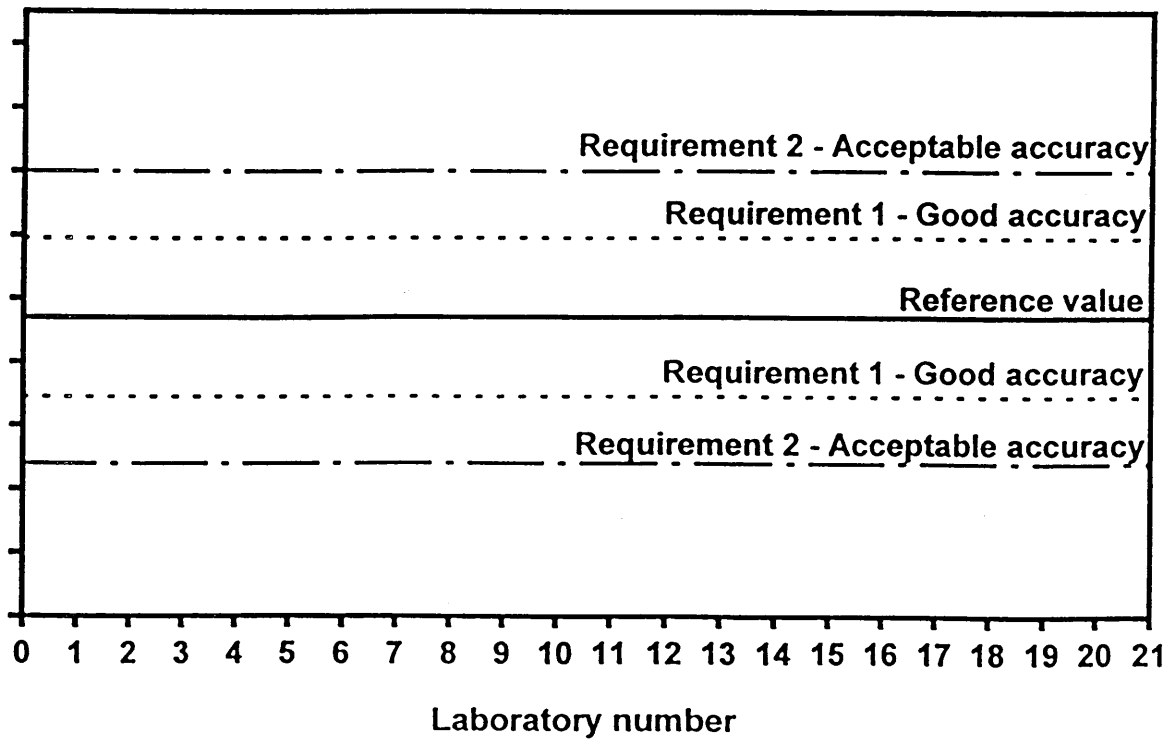
Table 6. Results reported by the participating laboratories, Series U - Welding fume filters

Laboratory	Filter no.	Cr	Fe	Mn	Ni	Pb	Zn
Arb.tils. Kr.sand	U-31	31,4	49,8	13,9	23,8	516	36,6
	U-68	32,0	51,0	14,3	24,3	523	37,5
Falconbridge	U-40	29,2	43,1	12,8	19,8	514	34,1
	U-49	28,0	44,0	12,7	20,9	513	33,8
HSL	U-64	26,9	41,4	12,3	20,4	448 *	32,2
	U-80	30,2	46,6	13,9	22,6	488	36,7
Kuopio	U-56	51 *	48	14	23	510	37
	U-70	54 *	47	13	22	515	36
Miljø-Kemi	U-38	29,7	45,9	14,2	24,0	577 *	34,1
	U-99	34,2	49,7	14,9	24,7	574 *	38,2
NIOH	U-53	29,400	45,375	12,837	16,387 *	490,11	36,075
	U-78	29,925	46,725	13,087	16,837 *	509,49	37,200
Oulun	U-34	30,45	46,60	13,58	24,25	539,8	35,83
	U-44	30,75	46,00	13,28	23,65	519,8	34,35
Sero AS	U-75	31,4	49,1	13,6	23,4	504	37,8
	U-85	31,0	51,9	13,8	23,5	507	37,6
Tinfos	U-21	30	55	19	24	495	47
	U-30	30	56	19	24	500	48
West Lab	U-81	31	48	14	24	539	36
	U-102	32	51	14	25	552	37
Reference value		**30,5**	**48,0**	**13,8**	**22,7**	**516**	**36,9**
Average		**30,4**	**48,1**	**14,1**	**23,2**	**514**	**37,2**
SD, µg		**1,6**	**3,7**	**1,8**	**1,5**	**17,4**	**3,9**
RSD, %		**5,3**	**7,7**	**12,7**	**6,4**	**3,4**	**10,4**

*: Outlier, result rejected after applying Grafs and Hennings method for evaluation of extreme analytical results. A significance level of 95 % was used.

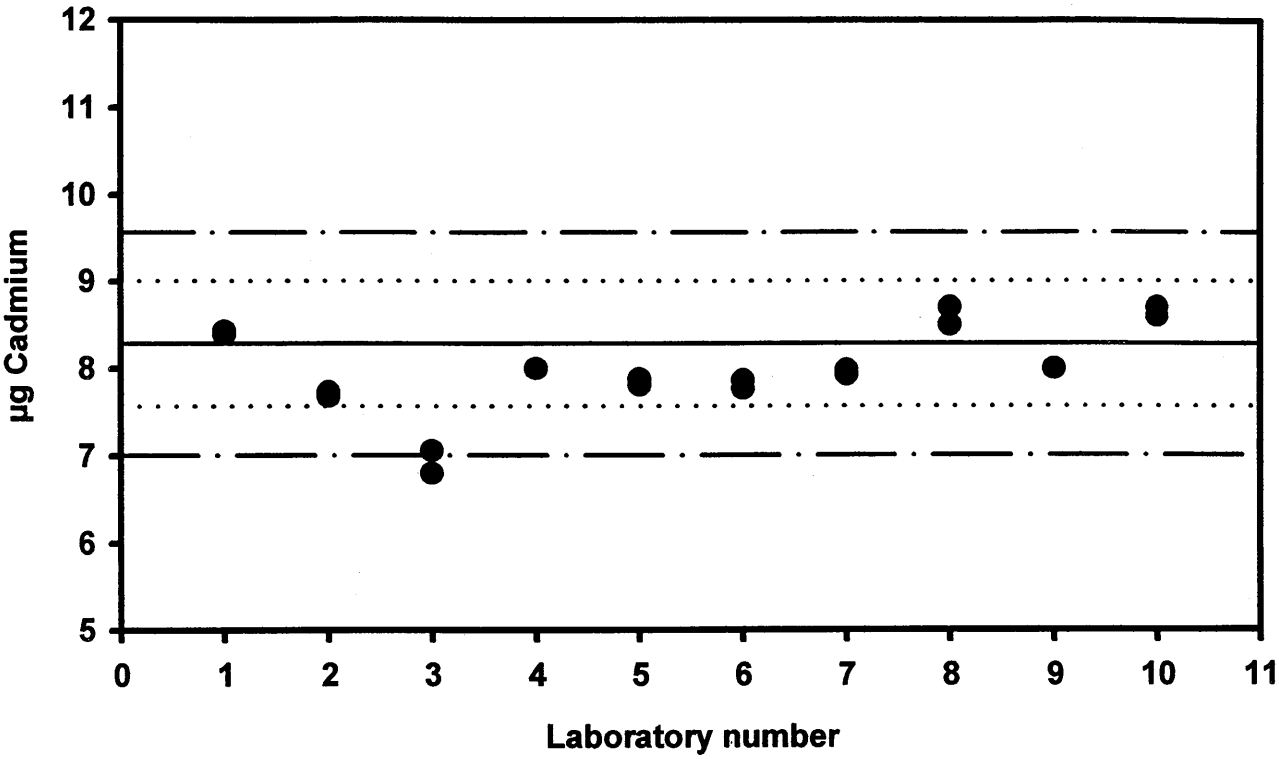
APPENDIX 2

The following figure is used to illustrate the reported values from each laboratory. The solid line represents the reference value, while the dotted lines indicate the requirements for «good» and «acceptable» results.



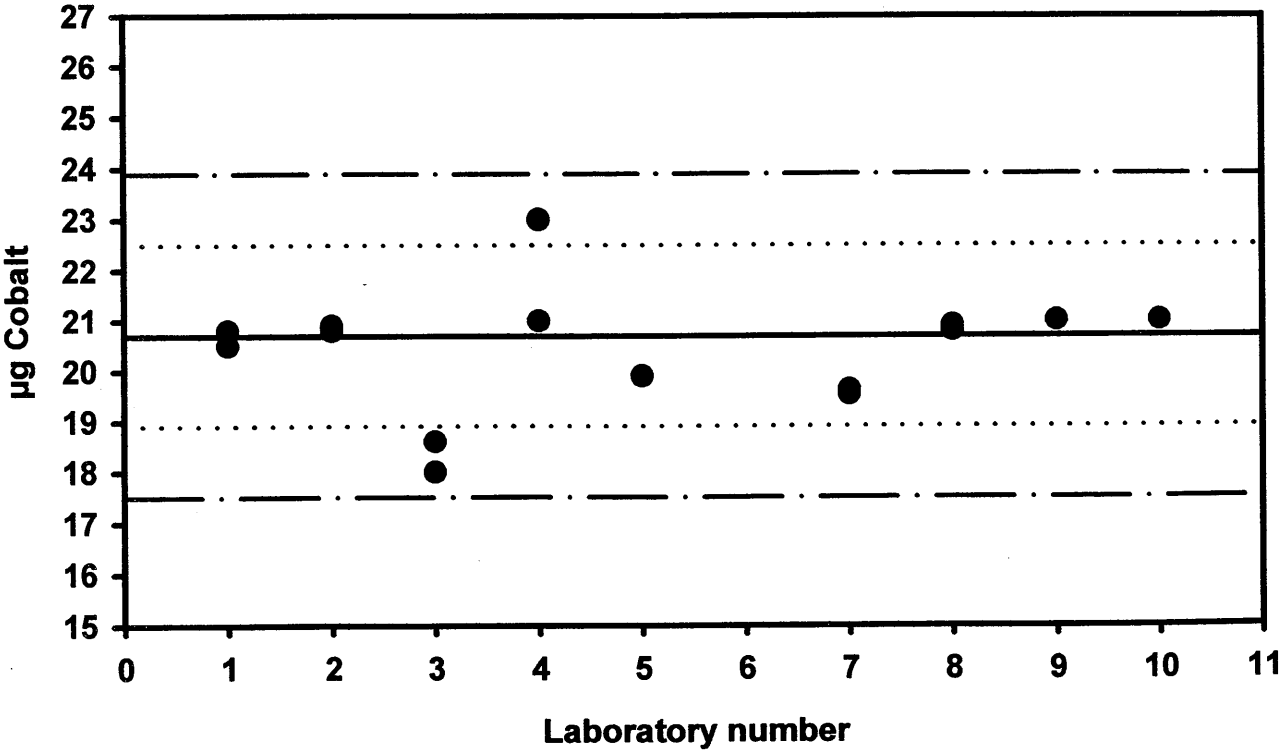
Cadmium - Series B-2

Reference value: 8,29 µg
Laboratory average: 8,0 µg



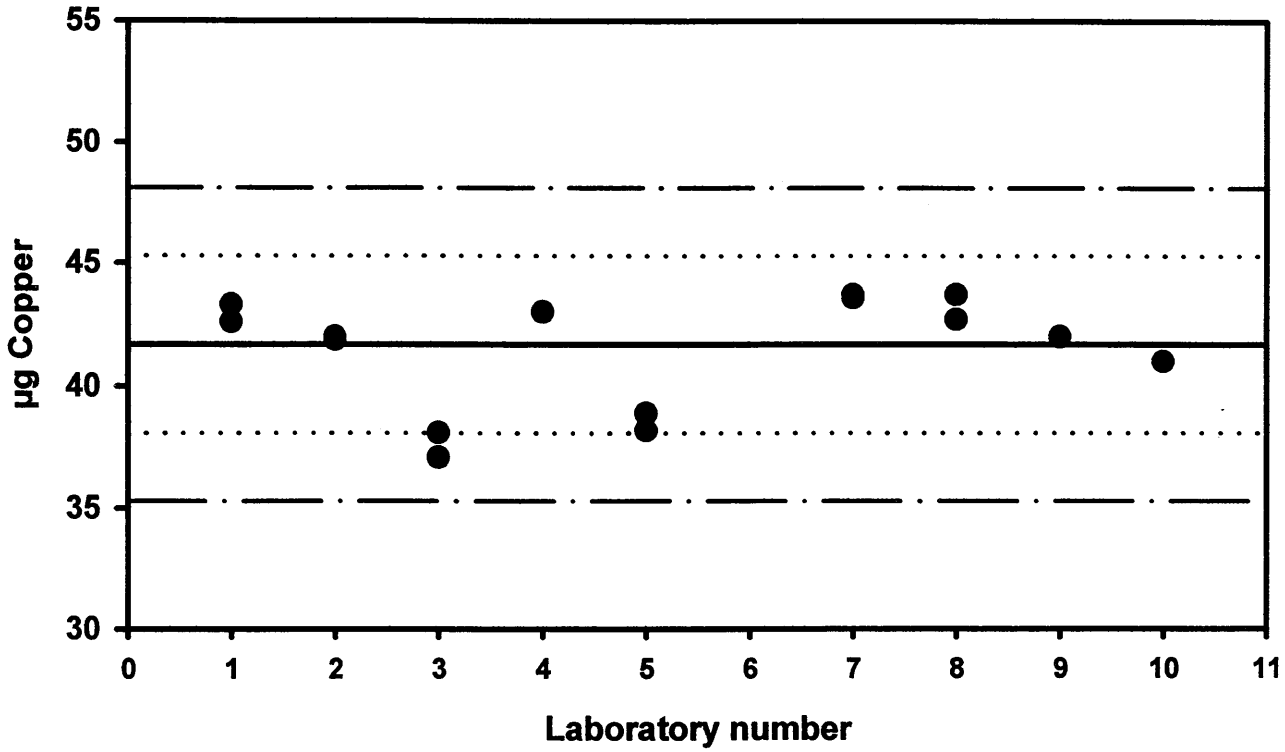
Cobalt - Series B-2

Reference value: 20,7 µg
Laboratory average: 20,5 µg



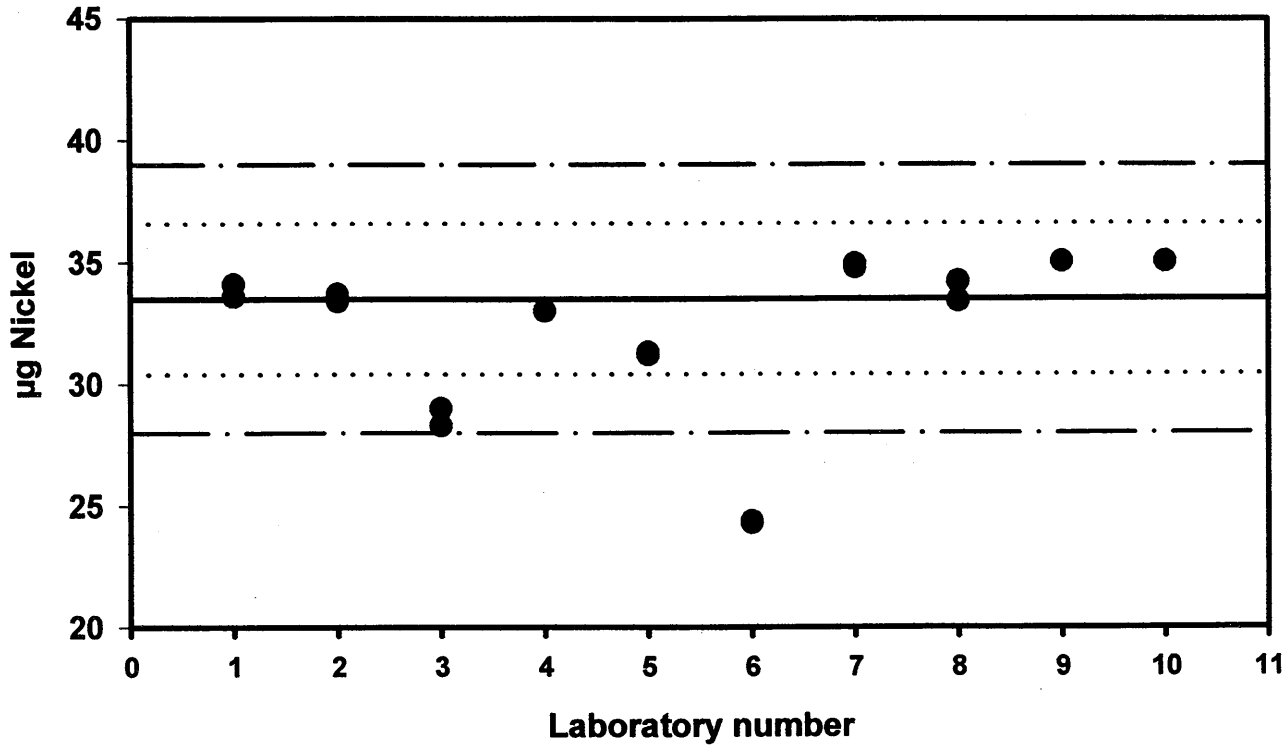
Copper - Series B-2

Reference value: 41,7 µg
Laboratory average: 41,5 µg



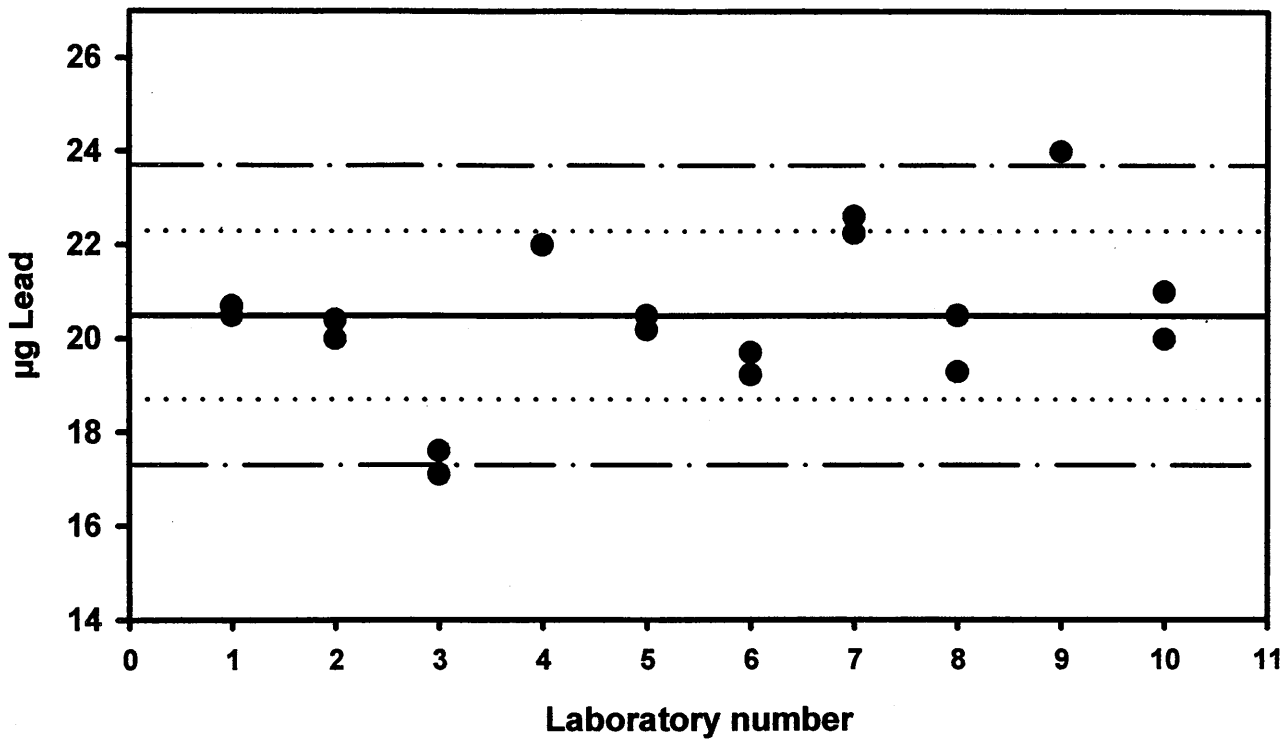
Nickel - Series B-2

Reference value: 33,5 µg
Laboratory average: 33,2 µg



Lead - Series B-2

Reference value: 20,5 µg
Laboratory average: 20,7 µg



Tin - Series B-2

Reference value: 21,0 µg
Laboratory average: 20,6 µg