



Title: Proficiency Testing for Measurement of Total Mass and Elements in Workplace Air Filters. Round 9.

Authors: Kari Dahl
Nils Petter Skaugset
Yngvar Thomassen

Co-ordinator: Kari Dahl

Date: 20.11.2001

Series: *STAMI Report Vol. 2, No.4 (2001)* **ISSN:**1502-0932

Summary:

In this proficiency testing programme laboratories from England, Lithuania, Finland, Sweden, Denmark and Norway have participated.

Filters and cassettes were distributed to the laboratories in March 2001. The laboratories were asked to pre-weigh the filters prior to exposure to welding fume, and to return the prepared filter cassettes by 20th of April 2001. Realistic work-room air and synthetically produced reference filters were distributed to the participants in May 2001 with a deadline for replies of 29th of June 2001.

The laboratories were asked to measure a number of occupational important elements listed in the enclosed protocol (Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Ti, Zn) and total mass.

Two out of the twelve laboratories completed the analytical protocol with a performance complying with all the assessment criteria.

Stikkord: Interkalibrering,
grunnstoffbestemmelse, gravimetri
Arbeidsatmosfære

Key words: Proficiency testing, elements,
total mass, workroom air filters

CONTENTS

	Summary	Page 2
	Abbreviations	Page 3
1	Introduction	Page 4
2	Participating laboratories	Page 5
3	Welding fume filters	Page 6
4	Reference filters	Page 6
5	Analytical conditions	Page 7
6	Reference values	Page 7
7	Assessment criteria	Page 8
8	Detection limit	Page 9
9	Results	Page 9
10	Discussion	Page 11
	Appendix 1	Page 13
	Appendix 2	Page 17

SUMMARY

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

Filters and cassettes were distributed to the laboratories in March 2001. The laboratories were asked to pre-weigh the filters prior to exposure to welding fume, and to return the prepared filter cassettes by 20th of April 2001. Welding fume filters (Series W) and synthetically produced reference filters (Series D) were distributed to the participating laboratories in May 2001 with a deadline of reply 29th of June 2001

In order to determine the "true" quantities of total mass and 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 W (welding fume) were based on the results using ICP-OES. The reference values for Series D (reference filters) were calculated and the theoretical values verified by chemical measurements.

In this round of the proficiency testing programme, twelve laboratories from England, Lithuania, Finland, Sweden, Denmark and Norway have participated. Each laboratory was asked to determine a total of eleven elements in two filter matrices (Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Ti, Zn) and total mass on the welding fume filters. Two of the participating laboratories completed the analytical protocol with a performance complying with all the assessment criteria.

The inter-laboratory variance for the individual elements after rejection of outliers shows acceptable agreement among the participants.

ABBREVIATIONS

EAAS:	Electrothermal Atomic Absorption Spectrometry
FAAS:	Flame Atomic Absorption Spectrometry
ICP-OES:	Inductively Coupled Plasma Optical Emission Spectrometry
ICP-QMS:	Inductively Coupled Plasma Quadruple Mass Spectrometry
ICP-MS:	Inductively Coupled Plasma Mass Spectrometry
ICP-SFMS:	Inductively Coupled Plasma Sector Field 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 measurements in Norway, as well as a regional laboratory for the Labour Inspectorate. As a national reference laboratory one of the objectives is to perform proficiency testing programmes for work environment measurements in commercial, public and industrial laboratories.

There is no official approval scheme for laboratories which offer work environment measurement services 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 assess the laboratory performance using routine procedures. The laboratories were therefore requested to include the samples in their normal analytical routine.

As in the previous round measurement of total mass was included in the testing programme. Filters and cassettes were distributed to the laboratories in March 2001. The laboratories were asked to pre-weigh the filters prior to exposure to welding fume, and to return the prepared filter cassettes by 20th of April 2001. The prepared samples were distributed in May 2001, with a deadline for replies of 29th of June. Each participant received duplicates of work-room air filters (Series W), reference filters spiked with known quantities of selected elements (Series D) and blank filters. The laboratories were asked to measure total mass (Series W) and the elements listed in the enclosed protocol.

2. PARTICIPATING LABORATORIES

Lab.no	Name, address	Name used
1	Falconbridge Nikkelverk A/S, Hovedlaboratoriet P.O.Box 457 N-4601 Kristiansand, Norway	Falconbridge
2	Health and Safety Laboratory Broad Lane UK-Sheffield S3 7HQ, United Kingdom	HSL
3	Centre of Occupational Medicine, Institute of Hygiene Etmonu str. 3 LT-2001 Vilnius, Lithuania	Inst. Of Hygiene
4	Kuopio Region Institut för Arbetshygien P.O.Box 93 FIN-70701 Kuopio, Finland	Kuopio
5	Miljø-Kemi, Dansk Miljøcenter A/S Smedeskovvej 38 DK-8464 Galten, Denmark	Miljø-Kemi
6	Molab as P.O.Box 5000 N-8601 Mo, Norway	Molab
7	National Institute of Occupational Health Lersø Parkallè 105 DK-2100 København Ø, Denmark	NIOH, Denmark
8	Oulu Regional Institute of Occupational Health Aapistie 1 FIN-90220 Oulu, Finland	Oulu
9	Sero AS, Avd. Norsk Analyse Center P.O.Box 24 N-1361 Billingstad, Norway	Sero
10	SGAB Analytica P.O.Box 511 S-183 25 Täby, Sweden	SGAB Analytica
11	West Lab AS Oljeveien 2 N-4056 Tananger, Norway	West Lab
12	X-lab AS Ibsensgt. 104 5052 Bergen	X-lab

3. WELDING FUME FILTERS

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 rate of airflow through the filters during the sampling period each position is equipped with a critical orifice. The rate of flow through each filter was measured at the beginning and at the end of the sampling period using a high precision flow meter in order to calculate an exact sampling air volume for each filter.

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. M000025A0) 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. AAWP002500).

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 using a variety of welding rods.

4. REFERENCE FILTERS

Reference filters were prepared by spiking 37 mm 0.8 μm cellulose ester membrane filters (Millipore art.no. AAWP 003700) with an aqueous solution containing elements with concentrations gravimetrically traceable to ultrapure metals or stoichiometrically well defined oxides. 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. The spiked analyte masses were measured by weighing each filter. Exact masses of the analytes of individual filters are obtained by using a gravimetric correction factor.

5. ANALYTICAL CONDITIONS

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

No.	Laboratory	Sample Preparation	Sample-volume	Analytical Method
1	Falconbridge	H ₂ O, HNO ₃ and HClO ₄ , hot plate digestion (+ 20 % HCl for Ag)	50 ml	ICP-OES Mettler AT 250
2	HSL	HNO ₃ /HF, Teflon autoclave with microwave assisted digestion.		ICP-OES Mettler AT201
3	Inst. Of Hygiene	HNO ₃ , HCl and HClO ₄ , Teflon autoclave with microwave assisted digestion.		EAAS Scaltec SBC 21
4	Kuopio	HNO ₃ /HCl, Teflon autoclave with microwave assisted digestion.		FAAS, EAAS Mettler Toledo AT261 DeltaRange
5	Miljø-Kemi	HNO ₃ , Teflon autoclave with microwave assisted digestion.		ICP-OES Difference weighing
6	Molab	HNO ₃ /HCl/HF, Teflon autoclave with microwave assisted digestion.		ICP-OES NS 4860
7	NIOH, Denmark	HNO ₃ /HCl, Teflon autoclave with microwave assisted digestion.		ICP-OES Micro balance
8	Oulu	HNO ₃ /HCl, microwave assisted digestion	25 ml	FAAS Mettler AT261
9	Sero	HNO ₃ /HCl/HF, Teflon autoclave, heated in laboratory oven.	14 ml	ICP-OES
10	SGAB Analytica	HNO ₃ /H ₂ O ₂ , in Teflon autoclave with microwave assisted digestion. For Ag-determination stabilizing with HCl		ICP-SFMS ICP-OES
11	West Lab	NIOSH Method 7300 and internal method A-003		ICP-OES
12	X-lab	HNO ₃ /H ₂ O ₂ , microwave assisted digestion	10	FAAS Mettler AT261 DeltaRange

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 14 ml.

All volumetric equipment that 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.

A semi microbalance of type Sartorius MC 210 P was used for the measurement of total mass. For the simultaneous measurement of all elements a Perkin-Elmer OPTIMA 3000 inductively coupled plasma optical emission spectrometer (ICP-OES) was used.

The reference values for Series W (welding fumes) are based on the results using ICP-OES (elements) and semi microbalance (total mass). Correction factors due to differences in sampling air volumes were used.

The spiked analyte masses of the reference filters (Series D) are measured by weighing. Exact values of individual filters are obtained by using a correction factor for each filter. The theoretical values are verified by chemical measurements.

The results for both filter media 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 with the following criteria:

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

Accuracy considered «good» or «acceptable» are dependent on the relationship between the concentration in a sample and the occupational exposure limit (OEL) for each individual element, expressed by the following formulas:

Requirement 1 (in %): $\log y = 4.8 \cdot 10^{-2} \cdot \log x^2 - 4.5 \cdot 10^{-1} \cdot \log x + 1.4$

where x is the proportion of element in sample relative to OEL (in %)

Requirement 2 (in %): Requirement 1*2

Analysis performed at the National Institute of Occupational Health in Oslo show that filter-to-filter variation was ≤ 0.7 % (relative standard deviation) for Series D and ≤ 1.3 % for Series W. In order to take filter homogeneity into account, two times the relative standard deviation is added.

The following limits emerge:

Requirement 1 or 2 + filter homogeneity (2 RSD)

8. DETECTION LIMIT

With regard to samples from workroom atmospheres, detection limits of 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 measurements must be no higher than 1% of the TLV.

Element	Threshold limit value, $\mu\text{g}/\text{m}^3$	Detection limit μg
Ag	100 (metal dust and fume)	1
Cd	20 (cadmium oxide calculated as Cd)	0.2
Co	20 (fume calculated as Co)	0.2
Cr	500 (Cr(II) and Cr(III) calculated as Cr)	5
Cu	100 (fume)	1
Fe	3000 (calculated as Fe)	30
Mn	1000 (fume calculated as Mn)	10
Ni	50 (calculated as Ni)	0.5
Pb	50 (metal dust and fume calculated as Pb)	0.5
Ti	5000 (titanium dioxide) (calculated as Ti 3000 $\mu\text{g}/\text{m}^3$)	30
Zn	5000 (zinc oxide) (calculated as Zn 4000 $\mu\text{g}/\text{m}^3$)	4
Total mass	5000 (welding fume)	50

9. RESULTS

The results that are reported by the participating laboratories are given in Appendix 1, Table 3 (Series D) and Table 4 (Series W).

The individual results are also presented graphically in Appendix 2.

The performances of the participating laboratories are summarised in Table 1 and 2.

The following symbols are used:

- Results complying with Requirement 1 («good accuracy») are indicated by: ●
- Results complying with Requirement 2 («acceptable accuracy») are indicated by: ○
- Results outside these two acceptance limits or reported with unacceptable detection limits are indicated «not acceptable»: ✎
- Results reported with unacceptable detection limits are indicated «not acceptable detection limit»: ✎

To comply with either Requirement 1 or Requirement 2 both parallel measurements must fall within the acceptance limits.

Table 1. Summary of results: Series D - Reference filters.

		Cd	Co	Cu	Fe	Mn	Ni,	Pb	Zn
	Reference value, µg	9.49	9.48	151	754	75.0	37.6	37.4	375
1	Falconbridge	○	●	●	●	●	●	●	●
2	HSL	○	↙	●	○	●	○	●	●
3	Inst. of hygiene	●	↙		↙	●	↙	↙	
4	Kuopio	●	●	●	●	●	●	●	●
5	Miljø-Kemi	↙	↙	↙	↙	↙	↙	↙	●
6	Molab	●	●	○	●	●	●	●	●
7	NIOH, Denmark	●			●	●		●	●
8	Oulu	●	●	↙	●	●	●	●	●
9	Sero	●	●	○	●	●	●	●	●
10	SGAB Analytica	●	●	●	●	●	●	○	●
11	West Lab	●	●	○	●	●	○	○	●
12	X-lab	●		○	●	●	↙	○	

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

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

		Total mass	Ag	Cr	Fe	Mn	Ni	Ti	Zn
	Reference value, µg	6580	57.5	98.7	235	89.9	18.3	28.6	116
1	Falconbridge	↙	○	●	●	●	●	●	●
2	HSL	○		○	●	●	↙	○	●
3	Inst. of hygiene	●		○	↙	●	↙		
4	Kuopio	○		↙	●	●	○		●
5	Miljø-Kemi	●		●	●	●	●	●	●
6	Molab	○		●	●	●	○	●	●
7	NIOH, Denmark	●		●	●	●			●
8	Oulu	○		●	●	●	●	↘	●
9	Sero	●	○	●	●	●	●	●	●
10	SGAB Analytica	○	↙	●	●	●	●	●	●
11	West lab	●	●	●	●	●	○	●	●
12	X-lab	●		●	●	●	●		●

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

10. DISCUSSION

In this round of the proficiency testing programme the participating laboratories were asked to determine a total of 13 elements in two filter matrices in addition to total mass on welding fume filters. Three out of the twelve laboratories completed the analytical protocol with a performance complying with Requirement 1 or 2. One laboratory reported results complying with Requirement 1 but did not determine all elements according to the protocol.

It should be noted that from 15th of February 2001 the Norwegian occupational exposure limits (OEL) for nickel and cobalt were lowered. This has influenced the analytical requirements for these two elements.

The inter-laboratory relative standard deviations after rejection of outliers range, depending on the element, varies from 3.8 to 18% (1.1 to 15 % in Round 8). In average for all elements the deviation is 8.7 % (6.1 % in Round 8) which shows acceptable agreement among the participants.

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.

A table summarising laboratory results for the nine proficiency testing programmes organised by National Institute of Occupational Health, Oslo since 1990 (Table 3) shows a decrease in extreme values during this period. A slightly worsening in reported values complying with Requirement 1 in this round is observed.

Table 3. Laboratory results for the last nine 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	301	70	14	15	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
8	13	15	152	87	5	8	4
9	12	14	171	73	15	12	1.8

APPENDIX 1

~~XXXXXXXXXX~~

Table 1. ICP-OES measurements of welding fume filters, Series W. Randomly selected filters analysed at the National Institute of Occupational Health, Oslo

Analytical Wave- length in nm	Filter no. W2 µg	Filter no. W13 µg	Filter no. W44 µg	Filter no. W62 µg	Filter no. W74 µg	Filter no. W83 µg	Filter no. W90 µg	Filter no. W105 µg	Filter no. W112 µg	Filter no. W114 µg
Ag 328.068	56.5	57.4	57.5	56.5	57.4	57.0	56.7	56.6	57.6	57.9
Ag 338.289	57.5	58.2	58.4	57.3	58.1	57.7	57.4	57.3	58.2	58.7
Cr 205.552	97.9	100	99.9	98.4	99.1	98.6	97.2	97.8	99.7	101
Cr 206.149	98.0	99.9	100.1	98.4	99.5	98.5	97.4	98.1	99.4	101
Cr 357.869	97.4	99.1	99.1	97.6	98.1	97.4	96.7	97.0	98.5	99.6
Fe 234.349	233	236	237	233	235	234	232	232	235	238
Fe 238.204	232	236	237	233	235	234	233	233	237	239
Fe 259.940	235	238	239	234	237	235	234	234	237	239
Fe 239.562	231	235	235	231	234	233	231	231	235	237
Mn 257.610	89.1	90.4	90.5	89.0	89.9	89.5	88.4	88.7	90.0	90.8
Mn 260.569	89.0	90.4	90.4	89.0	89.9	89.5	88.5	88.8	90.1	90.9
Mn 294.920	89.9	91.1	91.4	89.7	90.7	90.2	89.0	89.4	90.7	91.5
Ni 231.604	18.1	18.7	18.6	18.1	18.7	18.3	18.3	18.3	18.7	18.8
Ni 341.476	17.8	18.4	18.4	17.9	18.3	18.1	18.0	17.9	18.3	18.5
Ti 337.280	27.9	28.6	28.8	27.8	28.6	28.1	28.2	28.4	28.7	28.8
Ti 368.520	28.3	28.9	29.3	28.2	29.0	28.5	28.6	28.7	28.9	29.2
Ti 334.941	28.2	28.8	29.1	28.9	28.8	28.2	28.4	28.5	28.9	28.9
Zn 202.548	115	118	117	115	117	117	115	115	117	118
Zn 206.200	115	118	117	116	117	116	115	115	117	118
Zn 213.856	115	117	117	115	117	116	115	114	117	118

Table 2. Reference values, Series W - welding fume filters.

Filter no.	Total mass µg	Ag µg	Cr µg	Fe µg	Mn µg	Ni µg	Ti µg	Zn µg
W2	6510	57.0	97.8	233	89.4	18.0	28.1	115
W13	6590	57.8	99.7	236	90.6	18.5	28.8	118
W44	6610	57.9	99.7	237	90.8	18.5	29.1	117
W62	6540	56.9	98.2	233	89.2	18.1	28.1	115
W74	6600	57.8	98.9	235	90.2	18.5	28.8	117
W83	6550	57.3	98.2	234	89.8	18.2	28.3	116
W90	6560	57.0	97.1	232	88.6	18.2	28.4	115
W105	6520	56.9	97.7	232	89.0	18.1	28.5	115
W112	6610	57.9	99.2	236	90.2	18.5	28.8	117
W114	6710	58.3	100	238	91.1	18.7	29.0	118
Reference value	6580	57.5	98.7	235	89.9	18.3	28.6	116
SD	0.06	0.5	1.0	2.1	0.8	0.2	0.3	1.2
RSD, %	0.9	0.9	1.0	0.9	0.9	1.3	1.2	1.0

Table 3. Results reported by the participating laboratories, Series D - Reference Filters

No.	Laboratory	Filter no.	Correction factor	Reported results										Corrected results																																																																															
				Cd µg	Co µg	Cu µg	Fe µg	Mn µg	Ni µg	Pb µg	Zn µg	Cd µg	Co µg	Cu µg	Fe µg	Mn µg	Ni µg	Pb µg	Zn µg																																																																										
1	Falconbridge	D-24	1.002	8.13	9.02	147	735	73.2	36.5	36.1	368	8.15	9.04	147	737	73.4	36.6	36.2	369																																																																										
		D-62	1.003	8.16	9.06	147	734	73.0	36.3	36.2	367	8.18	9.09	147	736	73.2	36.4	36.3	368																																																																										
2	HSL	D-2	1.002	10.2	12.5	152	842	80.5	40.4	38.2	387	10.2	12.5	152	844	80.7	40.5	38.3	388																																																																										
		D-40	1.005	10.2	12.6	152	839	80.7	40.2	38.4	387	10.3	12.7	153	844	81.1	40.4	38.6	389																																																																										
3	Inst. of Hygiene	D-13	1.006	9.72	5.71		523.3	67.70	26.00	33.45		9.78	5.74		526.5	68.11	26.16	33.65																																																																											
		D-53	1.004	9.65	5.73		540.3	67.35	25.85	31.34		9.69	5.75		542.5	67.63	25.96	31.47																																																																											
4	Kuopio	D-17	1.004	10	9	151	758	79	36	37	375	10	9	152	761	79	36	37	376																																																																										
		D-72	1.005	10	9	152	728	79	36	39	369	10	9	153	731	79	36	39	371																																																																										
5	Miljø-Kemi	D-7	1.002	9.5	9.6	160	770	80	39	37	350	9.5	9.6	160	771	80	39	37	351																																																																										
		D-61	1.004	11.0	11	190	1000	97	45	44	400	11.0	11.0	*191	1004	*97	45	44	402																																																																										
6	Molab	D-37	1.003	9.40	9.44	142	732	72.8	36.8	37.4	371	9.43	9.47	142	735	73.0	36.9	37.5	372																																																																										
		D-74	1.002	9.32	9.28	142	725	72.1	36.9	36.8	371	9.34	9.30	142	727	72.3	37.0	36.9	372																																																																										
7	NIOH, Denmark	D-11	1.003	9.42			701.91	74.96		38.03	365.75	9.45			704.10	75.19		38.15	366.89																																																																										
		D-57	1.003	9.52			729.21	77.56		38.21	370.31	9.55			731.56	77.81		38.33	371.50																																																																										
8	Oulu	D-4	1.001	9.25	9.33	171	785	73.4	36.9	38.8	357	9.26	9.34	171	786	73.5	36.9	38.8	357																																																																										
		D-28	1.001	9.33	9.18	168	783	73.8	37.2	39.0	358	9.34	9.19	168	784	73.9	37.3	39.1	358																																																																										
9	Sero	D-22	1.003	9.61	10.1	159	796	78.2	39.2	37.3	375	9.64	10.1	160	799	78.5	39.3	37.4	376																																																																										
		D-33	1.003	9.18	10.0	158	789	76.6	39.6	36.8	372	9.21	10.0	158	791	76.8	39.7	36.9	373																																																																										
10	SGAB Analytica	D-47	1.005	9.05	9.08	154	817	75.5	37.2	33.6	377	9.10	9.13	155	821	75.9	37.4	33.8	379																																																																										
		D-67	1.005	9.46	9.02	155	821	75.8	37.8	33.7	379	9.51	9.06	156	825	76.2	38.0	33.9	381																																																																										
11	West Lab	D-41	1.004	10	9.3	160	780	79	41	41	400	10	9.3	161	783	79	41	41	401																																																																										
		D-59	1.002	10	9.3	160	770	79	40	42	400	10	9.3	160	772	79	40	42	401																																																																										
12	X-lab	D-9	1.002	9.57		152	785	76.6	33	33		9.59		152	786	76.7	33	33																																																																											
		D-70	1.005	9.03		137	693	69.0	32	37		9.08		138	697	69.4	32	37																																																																											
				Reference value																																																																																									
				9.49										9.48										151										754										75.0										37.6										37.4										37.5																			
				Average										9.56										9.39										154										760										75.7										36.9										37.3										376									
				SD, µg										0.62										1.65										8.53										93.2										3.94										4.45										2.88										14.3									
				RSD, %										6.5										17.5										5.5										12.3										5.2										12.1										7.7										3.8									

*: Outlier, result rejected after applying Grubb's test method for evaluation of extreme analytical results. A significance level of 95 % was used.

Table 4. Results reported by the participating laboratories, Series W – Welding fume filters

No.	Laboratory	Filter no.	Correction factor	Reported results							Corrected results								
				Total mass µg	Ag µg	Cr µg	Fe µg	Mn µg	Ni µg	Ti µg	Zn µg	Total mass µg	Ag µg	Cr µg	Fe µg	Mn µg	Ni µg	Ti µg	Zn µg
1	Falconbridge	W 12	0.989	7700	52.3	91.2	206	81.0	17.7	25.2	99.4	7618	51.7	90.2	204	80.1	17.5	24.9	98.3
		W 70	1.005	6700	54.1	94.8	212	83.7	18.1	26.4	102	6736	54.4	95.3	213	84.1	18.2	26.5	103
2	HSL	W 19	0.984	6180	99.7	224	88.0	18.8	35.4	110	6081	98.1	220	86.6	18.5	34.8	108		
		W 110	1.043	6800	108.0	244	95.5	20.6	38.2	118	7091	112.6	254	99.6	21.5	39.8	123		
3	Inst. of Hygiene	W 61	1.021	6620.0	84.68	164.4	77.15	12.36			6761.6	86.49	167.9	78.80	*12.62				
		W 107	1.043	6600.0	84.12	162.0	80.25	11.81			6882.4	87.72	168.9	83.68	*12.32				
4	Kuopio	W 56	1.005	6310	110	222	92	18		113	6344	111	223	92	18			114	
		W 109	1.037	6730	116	236	96	20		121	6982	120	245	100	21			126	
5	Miljø-Kemi	W 59	0.995	6500	110	270	86	19		32	6465	109	269	86	19			32	
		W 103	0.989	6600	110	260	87	19		32	6529	109	257	86	19			32	
6	Molab	W 49	1.011	6600*	100	223	90.3	19.1	30.7	111	6671	101	225	91.3	19.3	31.0	112		
		W 98	1.045	6800	102	229	92.3	19.6	30.8	113	7127	107	240	96.7	20.5	32.3	118		
7	NIOH, Denmark	W 8	0.989	6485.9	99.47	226.42	91.56			110.60	6416.5	98.41	224.00	90.58				109.42	
		W 64	1.005	6631.0	103.79	236.20	95.10			113.60	6666.5	104.53	237.46	95.61				114.21	
8	Oulu	W 24	0.984	6600	96.7	227	88.8	18.4	<125	111	6494	95.1	223	87.4	18.1	<123*	109		
		W 79	1.027	6800	103.7	240	93.4	19.3	<125	116	6982	106.5	246	95.9	19.8	<128*	119		
9	Sero	W 3	0.989	6510	52.3	101	231	88.7	18.7	27.7	107	6440	51.7	100	229	87.8	18.5	27.4	106
		W 87	0.989	6790	54.9	104	239	93.1	19.4	29.3	111	6717	54.3	103	236	92.1	19.2	29.0	110
10	SGAB Analytica	W 16	0.984	6370	0.121	93.8	249	88.1	17.7	28.1	113	6268	*0.1	92.3	245	86.7	17.4	27.6	111
		W 85	1.043	6720	0.196	98.4	255	93.1	18.4	30.0	120	7007	*0.2	102.6	266	97.1	19.2	31.3	125
11	West Lab	W 51	1.037	6700	59	105	250	98	20	27	130	6951	61	109	259	102	21	28	135
		W 113	1.021	6700	57	103	250	98	19	25	130	6843	58	105	255	100	19	26	133
12	X-lab	W 47	1.037	6700	102	244	97.1	17		124	6951	106	253	100.7	18			129	
		W 102	0.989	6300	94.3	218	89.4	17		98.8	6233	93.3	216	88.4	17			97.7	
				Reference value							Reference value								
				Average							Average								
				SD, µg							SD, µg								
				RSD, %							RSD, %								

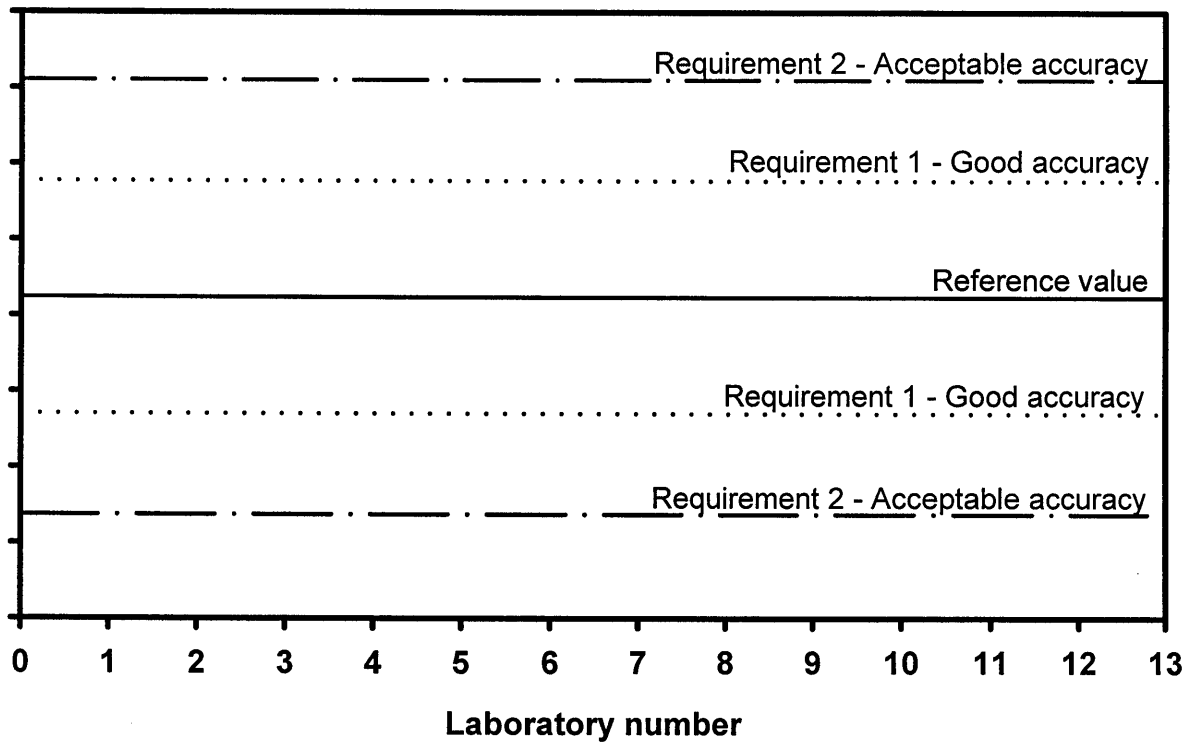
*: Outlier, result rejected after applying Grubb's test method for evaluation of extreme analytical results. A significance level of 95 % was used.

#: Result corrected for mix-up of filter samples during sampling of welding fume at National Institute of Occupational Health, Oslo.

†: Unacceptable detection limit

APPENDIX 2

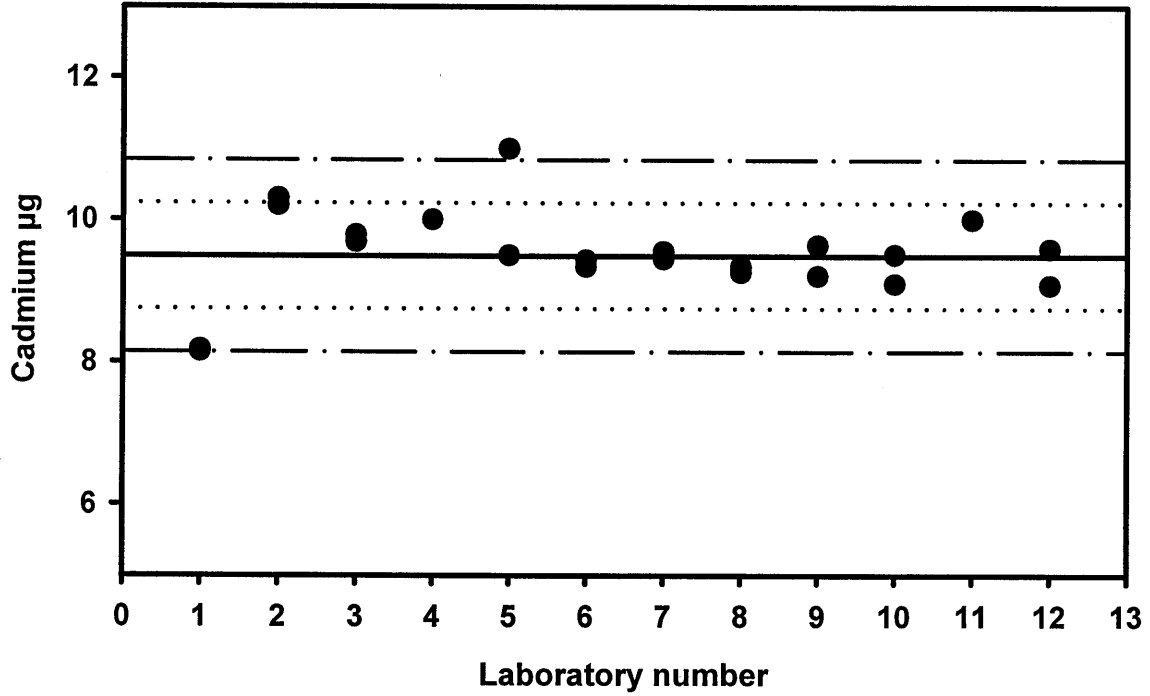
The following figure is used to illustrate the reported values from each laboratory. The solid line represents the reference value, while the dotted lines indicate the requirements for «good» and «acceptable» results.



Cadmium - Series D

Reference value: 9.49 µg

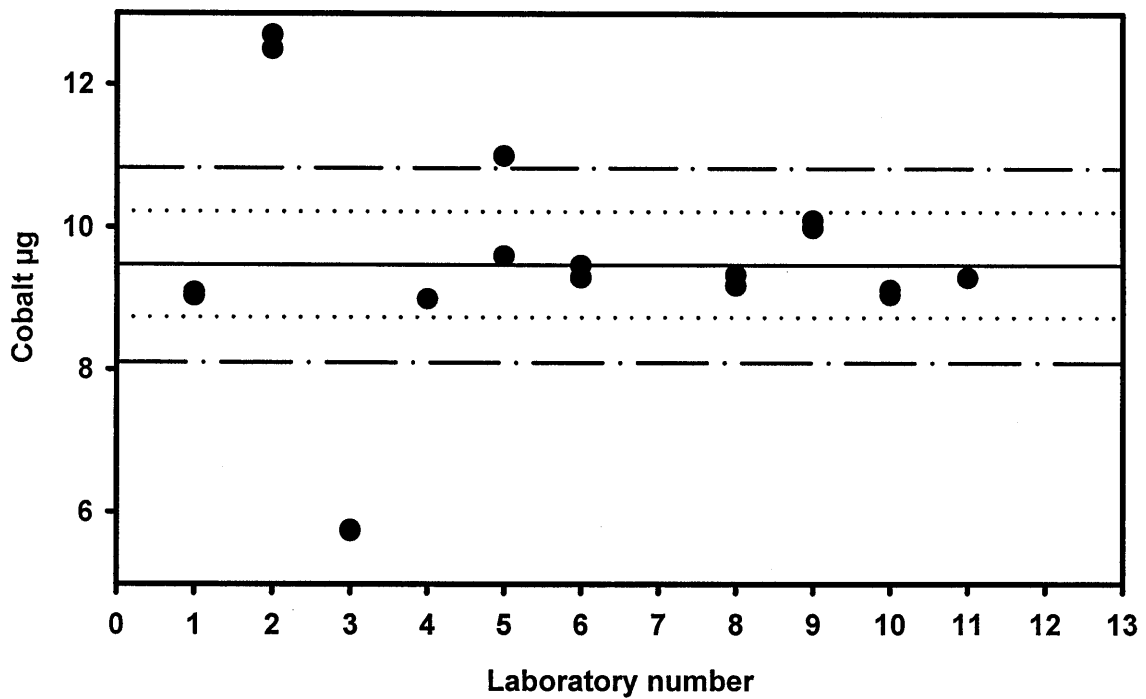
Laboratory average: 9.56 µg

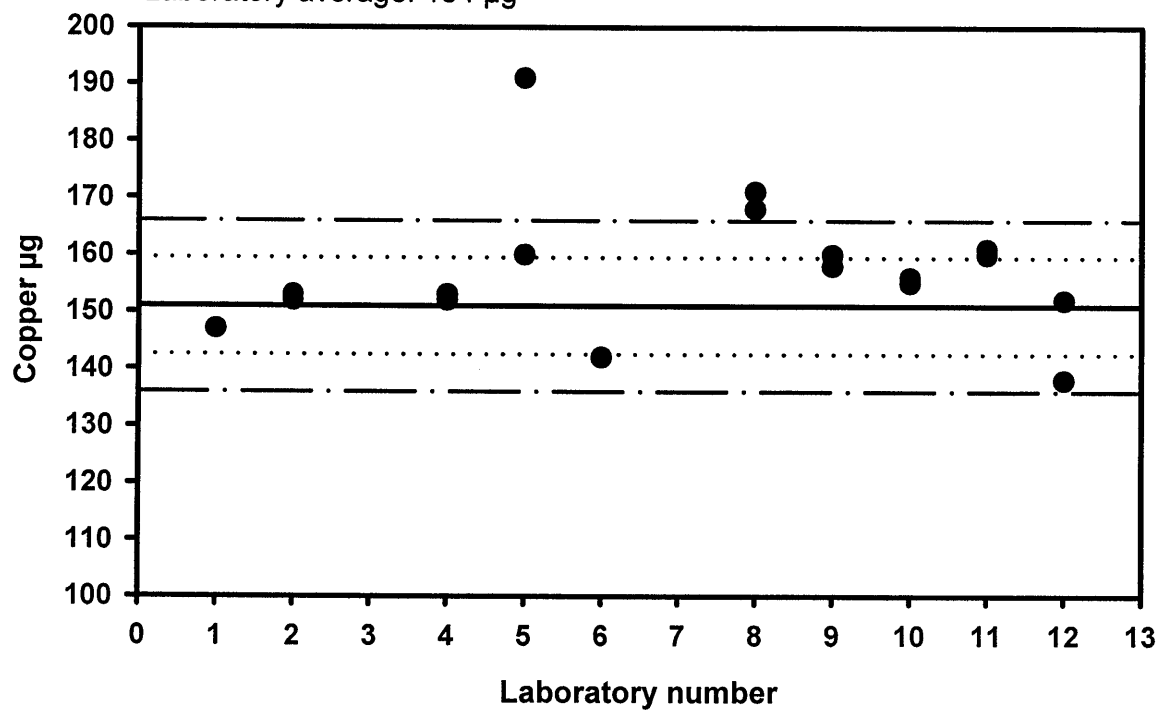
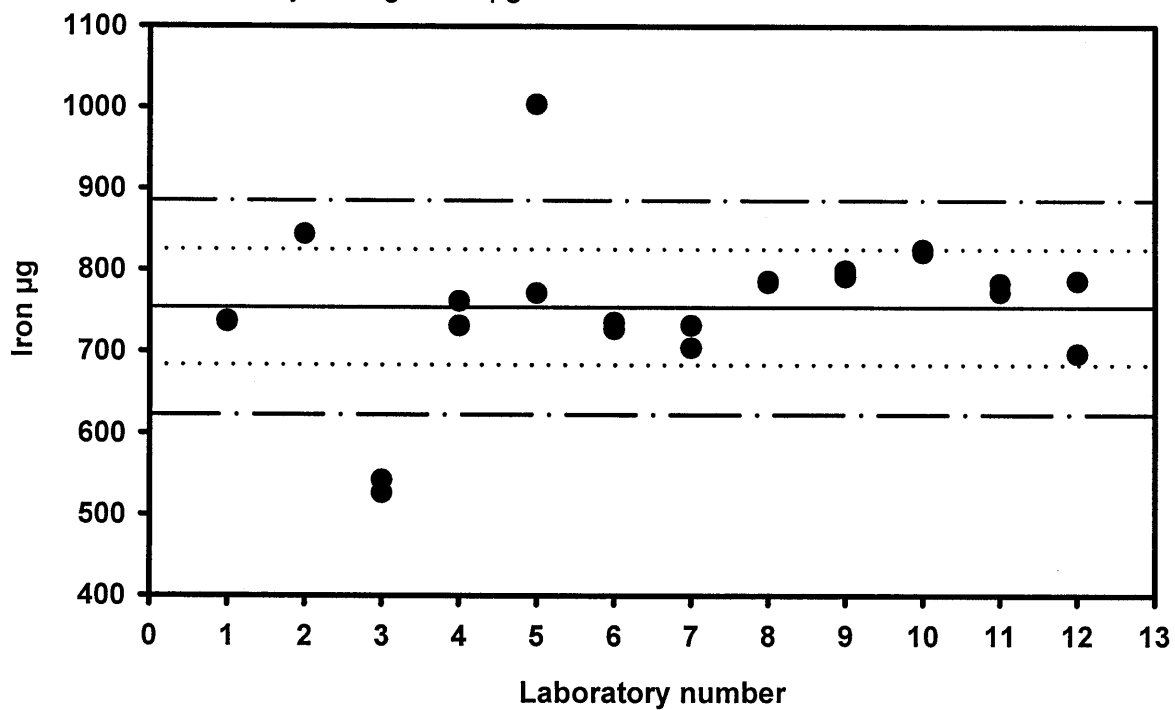


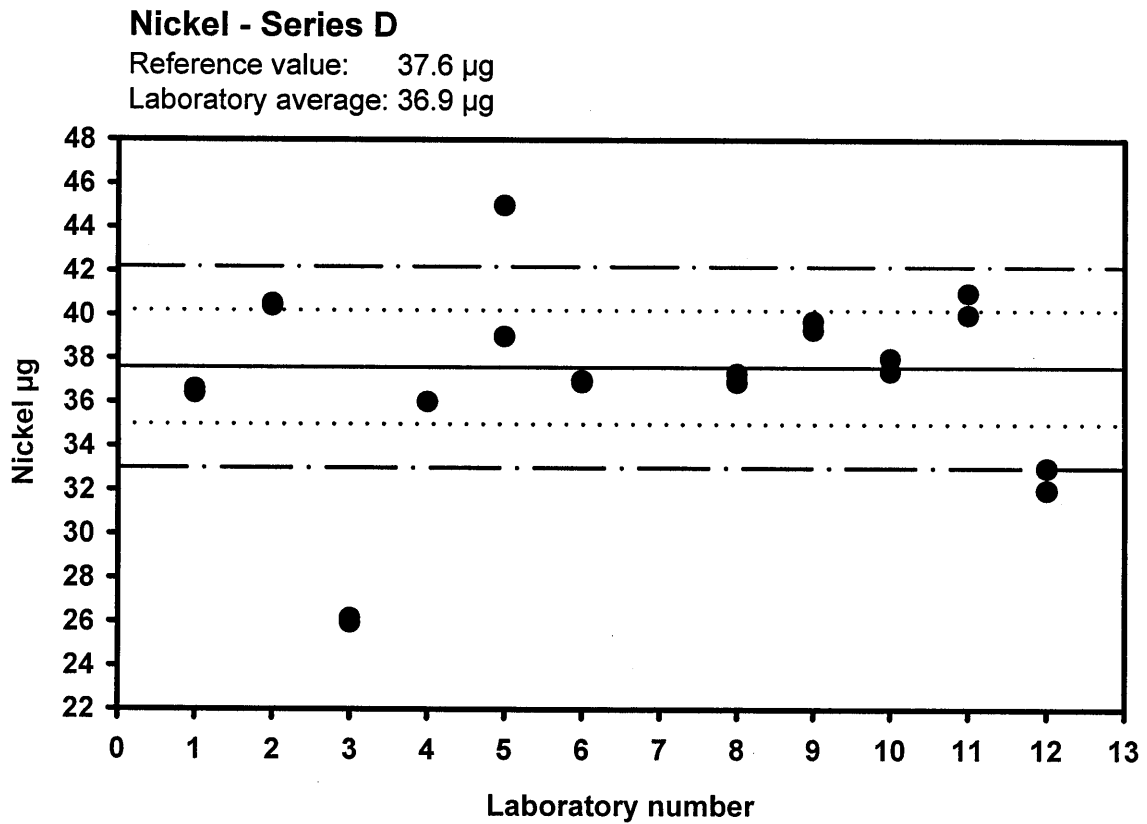
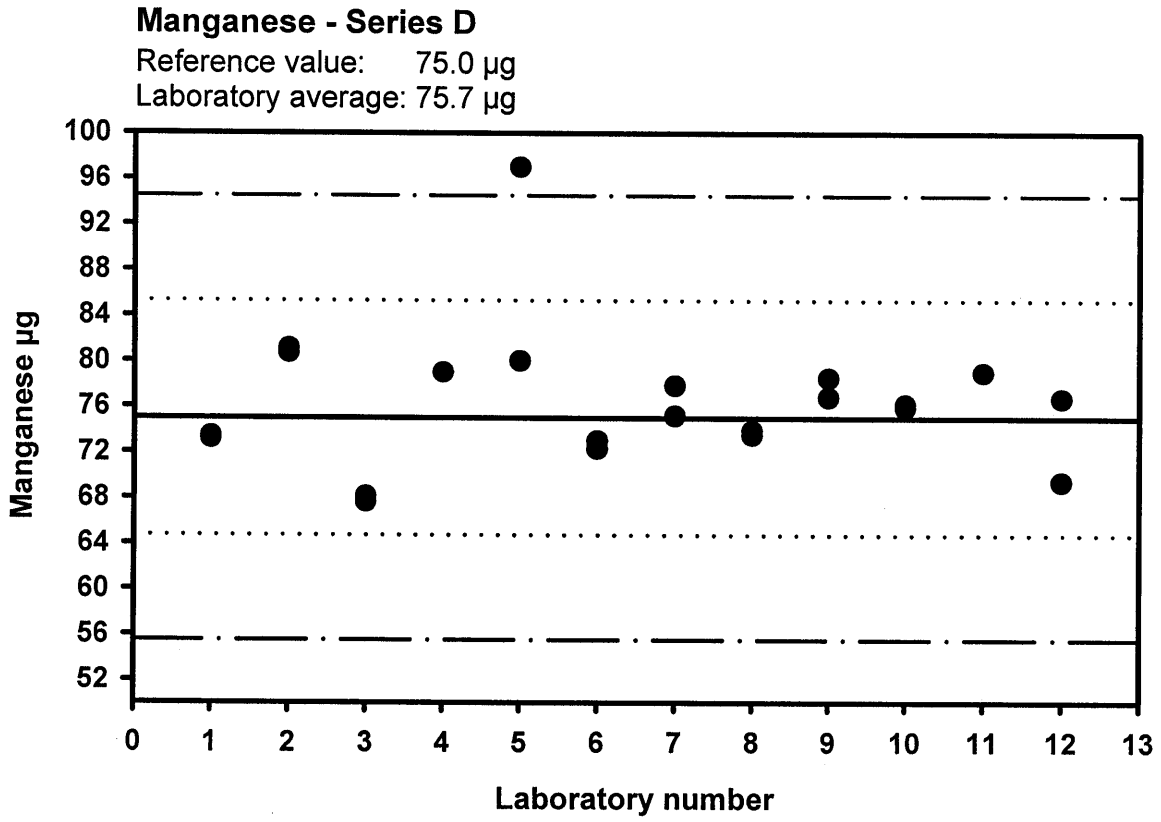
Cobalt - Series D

Reference value: 9.48 µg

Laboratory average: 9.39 µg



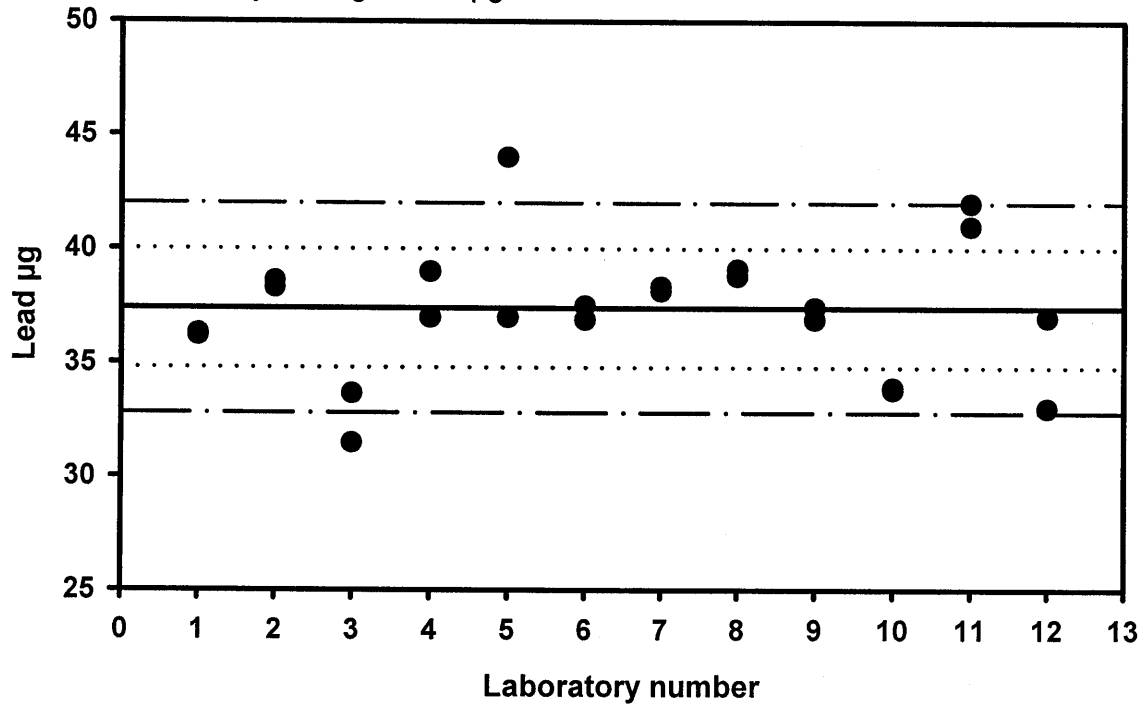
Copper - Series DReference value: 151 μg Laboratory average: 154 μg **Iron - Series D**Reference value: 754 μg Laboratory average: 760 μg 



Lead - Series D

Reference value: 37.4 μg

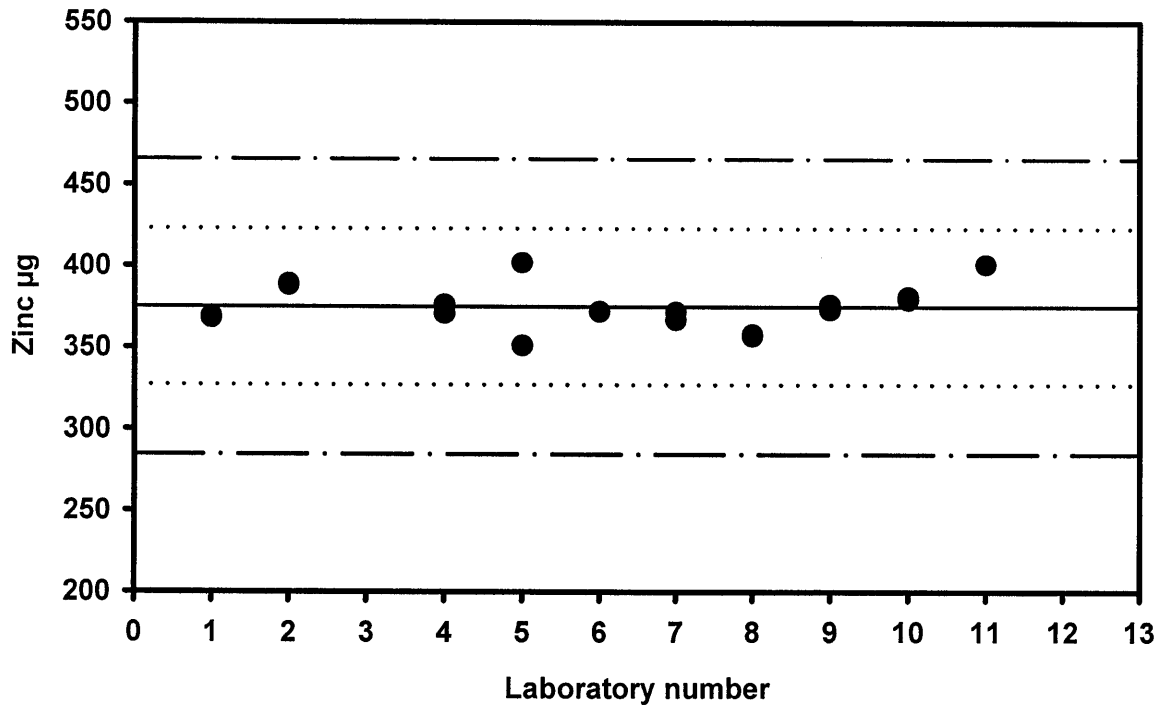
Laboratory average: 37.3 μg



Zink - Series D

Reference value: 375 μg

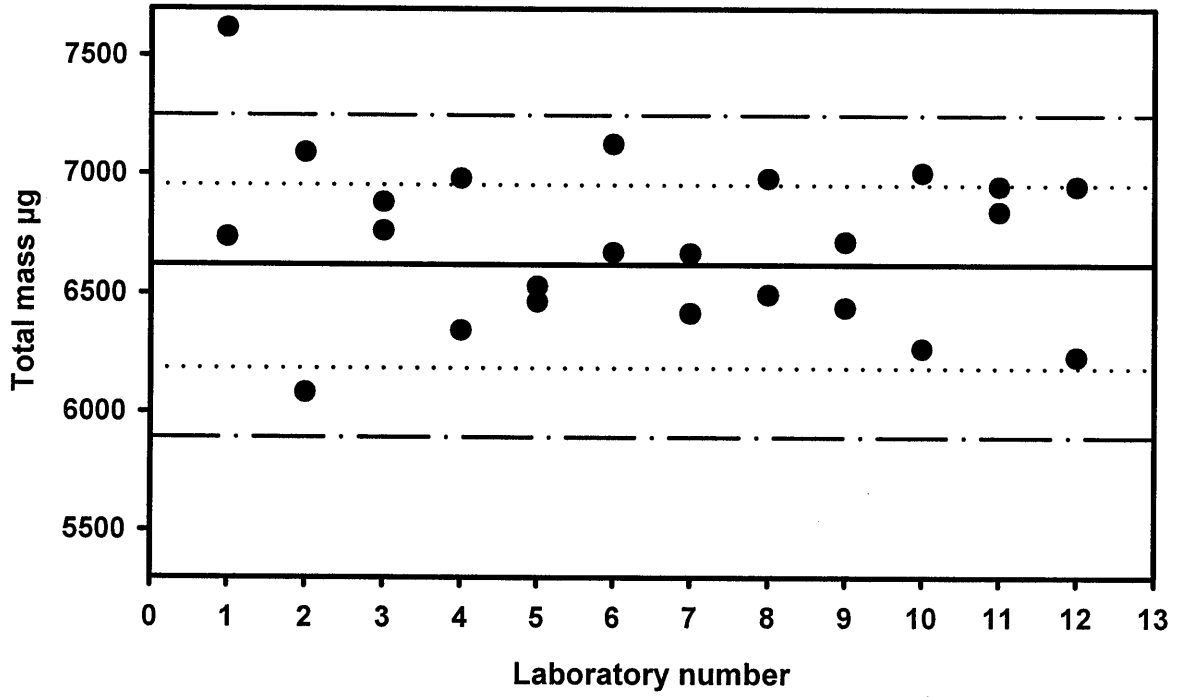
Laboratory average: 376 μg



Total mass - Series W

Reference value: 6620 μg

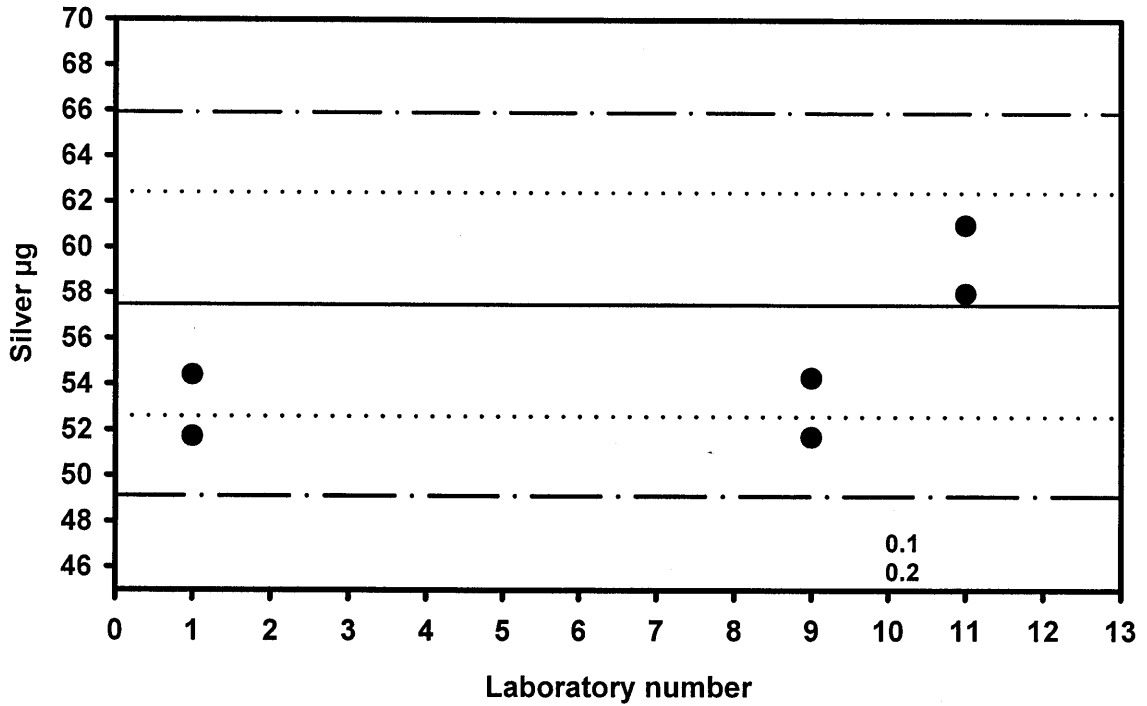
Laboratory average: 6719 μg



Silver - Series W

Reference value: 57.5 μg

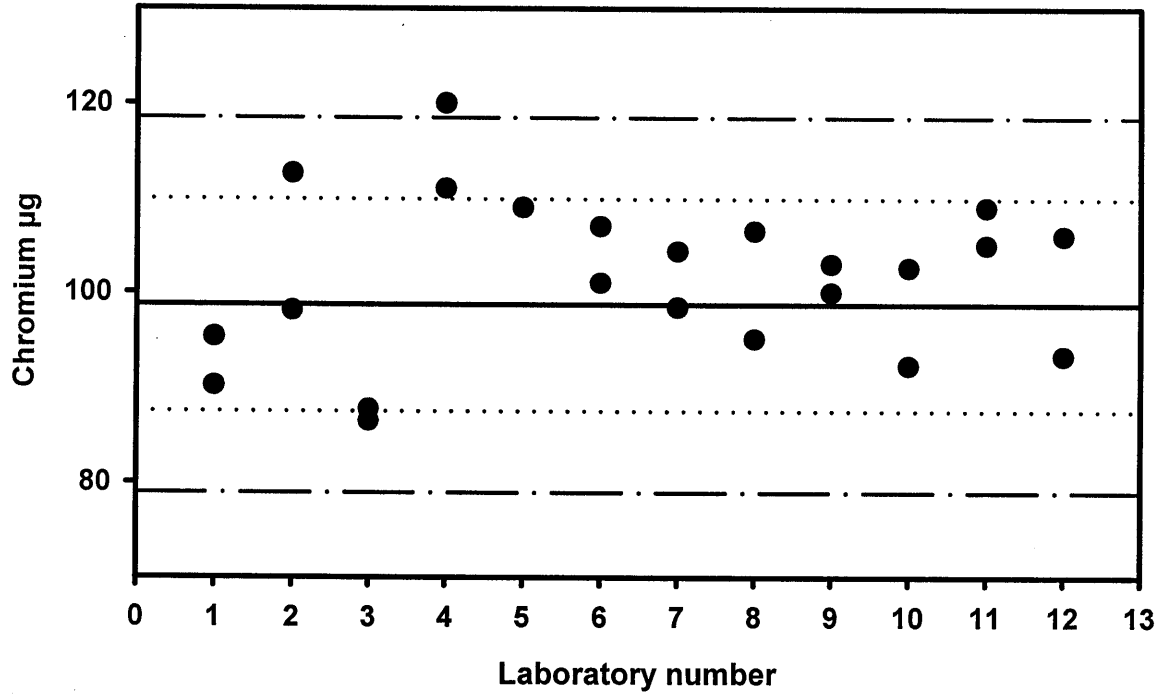
Laboratory average: 55.3 μg



Chromium - Series W

Reference value: 98.7 μg

Laboratory average: 101.8 μg



Iron - Series W

Reference value: 235 μg

Laboratory average: 232 μg

