



Title: Proficiency Testing for Measurement of Total Mass and Elements in Workplace Air Filters. Round 8.

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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 2000. The laboratories were asked to pre-weigh the filters prior to exposure to welding fume, and to return the prepared filter cassettes by 7th of April 2000. Realistic work-room air and synthetically produced reference filters were distributed to the participants in May 2000 with a deadline for replies of 16th of June 2000.

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

Four out of the thirteen laboratories completed the analytical protocol with a performance complying with the assessment criteria.

Stikkord: Interkalibrering,
grunnstoffbestemmelse, gravimetri
arbeidsatmosfære

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

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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 2000. The laboratories were asked to pre-weigh the filters prior to exposure to welding fume, and to return the prepared filter cassettes by 7th of April 2000. Welding fume filters (Series V) and synthetically produced reference filters (Series C) were distributed to the participating laboratories in May 2000.

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 V (welding fume) were based on the results using ICP-AES. The reference values for Series C (reference filters) were calculated and the theoretical values verified by chemical measurements.

In this round of the proficiency testing programme, thirteen laboratories from England, Lithuania, Finland, Sweden and Norway have participated. Each laboratory was asked to determine a total of fourteen elements in two filter matrices (Ag, Al, Be, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Ti, Zn) and total mass on the welding fume filters. Four out of the thirteen 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 good agreement among the participants.

ABBREVIATIONS

| | |
|----------|--|
| EAAS: | Electrothermal Atomic Absorption Spectrometry |
| FAAS: | Flame Atomic Absorption Spectrometry |
| ICP-AES: | Inductively Coupled Plasma Atomic Emission Spectrometry |
| ICP-OES: | Inductively Coupled Plasma Optical Emission Spectrometry |
| ICP-QMS: | Inductively Coupled Plasma Quadropole Mass 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 measurements in Norway, as well as a regional laboratory for the Labour Inspectorates. As a national reference laboratory one of the objectives is to carry out 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.

In this round measurements of total mass was included in the testing programme. Filters and cassettes were distributed to the laboratories in March 2000. The laboratories were asked to pre-weigh the filters prior to exposure to welding fume, and to return the prepared filter cassettes by 7th of April 2000. The prepared samples were distributed in May 2000, with a deadline for replies of 16th of June. Each participant received duplicates of work-room air filters (Series V), reference filters spiked with known quantities of selected elements (Series C) and blank filters. The laboratories were asked to measure total mass (Series V) and the elements listed in the enclosed protocol.

2. PARTICIPATING LABORATORIES

| Lab.no | Name, address | Name used |
|--------|--|-------------------------|
| 1 | Analyselaboratoriet, Høgskolen i Agder Serviceboks 422 N-4604 Kristiansand, Norway | Analyselaborato riet |
| 2 | Elkem ASA Bremanger Smelteverk N-6930 Svelgen, Norway | Elkem Bremanger |
| 3 | Falconbridge Nikkelverk A/S, Hovedlaboratoriet P.O.Box 457 N-4601 Kristiansand, Norway | Falconbridge |
| 4 | Health and Safety Laboratory Broad Lane UK-Sheffield S3 7HQ, United Kingdom | HSL |
| 5 | Centre of Occupational Medicine, Institute of Hygiene Etmonu str. 3 LT-2001 Vilnius, Lithuania | Inst. of Hygiene |

| | | |
|----|---|----------------|
| 6 | Kuopio Region Institut för Arbetshygien P.O.Box 93 FIN-70701 Kuopio, Finland | Kuopio |
| 7 | Miljø-Kemi, Dansk Miljøcenter A/S Smedeskovvej 38 DK-8464 Galten, Denmark | Miljø-Kemi |
| 8 | Molab as P.O.Box 5000 N-8601 Mo, Norway | Molab |
| 9 | National Institute of Occupational Health Lersø Parkallè 105 DK-2100 København Ø, Denmark | NIOH |
| 10 | Sero AS, Avd. Norsk Analyse Center P.O.Box 24 N-1361 Billingstad, Norway | Sero AS |
| 11 | SGAB Analytica P.O.Box 511 S-183 25 Täby, Sweden | SGAB Analytica |
| 12 | Tinfos Jernverks as, Øye Smelteverk P.O.Box 246 N-4481 Kvinesdal, Norway | Tinfos |
| 13 | 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 threshold limit values of contaminations in workroom atmospheres (provided that the simulated filter has been exposed to one cubic meter of air) except for Mo and Zn. 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 uncertainties (half width of the 95% confidence intervals) for the individual elements is based on scientific judgement and represents an estimate of the combined effects of any error, attributed to gravimetric and volumetric procedures, purity of the source material and possible contamination throughout the production steps.

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 |
|---------------------|---|---------------|---------------------------|
| Analyselaboratoriet | HNO ₃ /HCl/HF in teflon autoclave with microwave assisted digestion. | 50 ml | FAAS Mettler AT 261 |
| Elkem Bremanger | | | |
| Falconbridge | H ₂ O, HNO ₃ and HCl, hot plate digestion. | 50 ml | ICP-OES Mettler AT 250 |
| HSL | HNO ₃ /HF, teflon autoclave with microwave assisted digestion. | | ICP-AES |
| Inst. of Hygiene | HNO ₃ , teflon autoclave with microwave assisted digestion. | | EAAS Scaltec SBC 21 |
| Kuopio | HNO ₃ /HCl, teflon autoclave with microwave assisted digestion. | | FAAS, EAAS |
| Miljø-Kemi | HNO ₃ , teflon autoclave with microwave assisted digestion. | | ICP-AES Micro balance |
| Molab as | HNO ₃ /HCl, teflon autoclave with microwave assisted digestion. | | ICP-AES Mettler AT 261 |
| NIOH | HNO ₃ /HCl, teflon autoclave with microwave assisted | | ICP-AES |

| | | | |
|----------------|--|--------|---------------------------|
| | digestion. | | |
| Sero | HNO ₃ /HCl/HF, teflon autoclave, heated in laboratory oven. | 14 ml | ICP-AES |
| SGAB Analytica | Series C: HNO ₃ /H ₂ O ₂ , Series V: HNO ₃ /HCl/HF, both series in teflon autoclave with microwave assisted digestion. | | ICP-QMS ICP-AES |
| Tinfos | HNO ₃ /HCl, teflon autoclave with microwave assisted digestion. | 100 ml | FAAS Mettler AE 163 |
| 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 total mass a semi micro balance of type Sartorius MC 210 P was used.

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

The reference values for Series V (welding fumes) are based on the results using ICP-AES (elements) and semi micro balance (total mass). The results are given in Appendix 1, table 1 and 2.

The spiked analyte masses of the reference filters (Series C) 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 measurements.

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 ± 5 % | Better than ± 10 % |
| 10 % | Better than ± 10 % | Better than ± 20 % |
| 1 % | Better than ± 25 % | Better than ± 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:

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

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

Analysis performed at the National Institute of Occupational Health in Oslo show that filter-to-filter variation was ≤ 1 % (relative standard deviation) for Series C and $\leq 1,5$ % for Series V. 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 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 |
| Al | 5000 (welding fume) | 50 |
| Be | 1 | 0,01 |
| Cd | 20 | 0,2 |
| Co | 50 (fume) | 0,5 |
| Cr | 500 | 5 |
| Cu | 100 (fume) | 1 |
| Fe | 3000 | 30 |

| | | |
|------------|--------------------------|-----|
| Mn | 1000 (fume) | 10 |
| Mo | 5000 (soluble compounds) | 50 |
| Ni | 100 | 1 |
| Pb | 50 | 0,5 |
| Ti | 5000 (titanium dioxide) | 50 |
| Zn | 4000 | 4 |
| Total mass | 5000 (welding fume) | 50 |

9. RESULTS

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

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 C - Reference filters.

| | | Be | Cd | Co | Mo | Ni | Pb | Zn |
|----|---------------------|-----|------|------|------|------|------|-----|
| | Reference value, µg | 1,7 | 16,9 | 42,3 | 42,7 | 68,4 | 42,0 | 256 |
| 1 | Analyselaboratoriet | | ● | ● | | ● | ○ | ● |
| 2 | Elkem Bremanger | | | | | | | |
| 3 | Falconbridge | ↙ | ● | ● | ● | ● | ● | ● |
| 4 | HSL | ● | ● | ● | ● | ● | ● | ● |
| 5 | Inst. of hygiene | | ● | | | ● | ● | ● |
| 6 | Kuopio | | ● | ● | | ↙ | ● | ● |
| 7 | Miljø-Kemi | ● | ● | ● | ● | ○ | ○ | ● |
| 8 | Molab as | | ● | ● | | ● | ↙ | ● |
| 9 | NIOH | | ● | | | | ↙ | ● |
| 10 | Sero | ● | ● | ● | ● | ● | ● | ● |
| 11 | SGAB Analytica | ● | ● | ● | ● | ● | ● | ● |
| 12 | Tinfos | ● | ● | ● | | ● | ● | ● |
| 13 | West Lab | | ● | ● | ● | ● | ● | ● |

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

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

| | | Total mass | Ag µg | Al µg | Cr µg | Cu µg | Fe µg | Mn µg | Ti µg |
|----|---------------------|------------|----------|----------|----------|----------|----------|----------|----------|
| | Reference value | 4,7 mg | 77,7 | 57,3 | 44,8 | 21,4 | 382 | 77,4 | 27,3 |
| 1 | Analyselaboratoriet | ● | | ⚡ | ● | ● | ● | ● | |
| 2 | Elkem Bremanger | ● | | | | | | | |
| 3 | Falconbridge | ⚡ | ○ | ○ | ● | ● | ● | ● | ● |
| 4 | HSL | ● | ⚡ | ● | ● | ● | ● | ● | ● |
| 5 | Inst. of hygiene | ● | ⚡ | ⚡ | ● | ⚡ | ⚡ | ● | |
| 6 | Kuopio | | | ○ | ● | ● | ● | ○ | |
| 7 | Miljø-Kemi | ● | | ● | ● | ● | ● | ● | ● |
| 8 | Molab as | ● | | ● | ● | ● | ● | ● | |
| 9 | NIOH | | | | ● | | ● | ● | |
| 10 | Sero | ● | ● | ● | ● | ● | ● | ● | ● |
| 11 | SGAB Analytica | ● | ⚡ | ● | ● | ● | ● | ● | ● |
| 12 | Tinfos | ● | ● | ● | ● | ● | ● | ● | ● |
| 13 | 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 14 elements in two filter matrices in addition to total mass on welding fume filters. Four out of the thirteen 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 1,1 to 15% (3,4 to 13 % in Round 7). In average for all elements the deviation is 6,1 % (7,3 % in Round 7) which shows good 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.

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 | 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 |
| 8 | 13 | 15 | 152 | 87 | 5 | 8 | 4 |

APPENDIX

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

| Analytical Wave-length in nm | Filter no. | Filter no. | Filter no. | Filter no. | Filter no. | Filter no. | Filter no. | Filter no. | Filter no. | Filter no. |
|------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| | V13 µg | V33 µg | V49 µg | V56 µg | V57 µg | V58 µg | V60 µg | V61 µg | V62 µg | V63 µg |
| Ag 328.068 | 74,4 | 76,7 | 77,8 | 76,6 | 77,3 | 75,8 | 75,2 | 74,8 | 75,6 | 74,8 |
| Ag 338.289 | 74,4 | 76,9 | 77,8 | 76,5 | 77,4 | 75,8 | 75,1 | 74,8 | 75,7 | 74,7 |
| Al 308.215 | 58,9 | 61,0 | 62,0 | 61,1 | 61,5 | 60,3 | 59,9 | 59,8 | 60,3 | 59,5 |
| Al 394.401 | 60,7 | 63,0 | 63,7 | 62,9 | 64,0 | 64,0 | 63,1 | 62,7 | 63,8 | 63,3 |
| Al 396.152 | 59,9 | 62,1 | 62,5 | 61,5 | 61,9 | 61,3 | 60,6 | 60,2 | 61,0 | 60,7 |
| Cr 205.552 | 45,1 | 46,3 | 47,2 | 45,9 | 46,6 | 46,3 | 45,7 | 45,4 | 46,2 | 45,1 |
| Cr 206.149 | 45,7 | 46,0 | 46,9 | 45,3 | 46,0 | 45,9 | 45,3 | 44,3 | 45,1 | 44,6 |
| Cr 267.716 | 44,8 | 45,9 | 46,9 | 45,5 | 46,1 | 45,6 | 45,2 | 44,8 | 45,6 | 44,5 |
| Cr 357.869 | 44,9 | 46,2 | 47,1 | 45,9 | 46,5 | 45,2 | 44,7 | 45,3 | 46,0 | 45,1 |
| Cu 224.700 | 21,3 | 22,0 | 22,4 | 22,2 | 22,3 | 21,9 | 21,7 | 21,7 | 22,0 | 21,4 |
| Cu 324.754 | 20,9 | 21,5 | 21,9 | 21,5 | 21,7 | 21,1 | 20,9 | 20,9 | 21,1 | 20,6 |
| Cu 327.396 | 21,3 | 22,0 | 22,4 | 22,2 | 22,5 | 21,8 | 21,7 | 21,8 | 22,0 | 21,5 |
| Fe 234.349 | 373 | 384 | 392 | 384 | 388 | 387 | 383 | 376 | 382 | 377 |
| Fe 238.204 | 369 | 379 | 386 | 377 | 381 | 379 | 375 | 368 | 373 | 368 |
| Fe 259.940 | 372 | 383 | 391 | 384 | 387 | 385 | 382 | 376 | 381 | 376 |
| Fe 239.562 | 366 | 376 | 383 | 374 | 377 | 376 | 371 | 362 | 367 | 364 |
| Mn 257.610 | 77,1 | 79,4 | 80,6 | 78,8 | 79,7 | 79,1 | 78,2 | 77,0 | 78,1 | 77,2 |
| Mn 260.569 | 77,0 | 79,2 | 80,3 | 78,4 | 79,3 | 78,7 | 77,8 | 76,5 | 77,7 | 76,8 |
| Mn 294.920 | 77,9 | 80,3 | 81,5 | 79,8 | 80,9 | 80,5 | 79,6 | 78,5 | 79,5 | 78,6 |
| Ti 368.520 | 28,5 | 29,5 | 30,3 | 30,1 | 30,3 | 29,8 | 29,5 | 29,4 | 29,8 | 29,1 |
| Ti 334.941 | 28,6 | 29,5 | 30,2 | 29,8 | 30,0 | 29,7 | 29,3 | 29,0 | 29,3 | 29,0 |
| Ti 336.121 | 28,1 | 29,0 | 29,7 | 29,1 | 29,2 | 28,9 | 28,5 | 28,1 | 28,4 | 28,1 |

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

| Filter no. | Ag µg | Al µg | Cr µg | Cu µg | Fe µg | Mn µg | Ti µg |
|-----------------|-------------|-------------|-------------|-------------|------------|-------------|-------------|
| V13 | 74,4 | 59,9 | 45,1 | 21,1 | 370 | 77,4 | 28,4 |
| V33 | 76,8 | 62,0 | 46,1 | 21,8 | 381 | 79,6 | 29,3 |
| V49 | 77,8 | 62,7 | 47,0 | 22,2 | 388 | 80,8 | 30,1 |
| V56 | 76,6 | 61,8 | 45,6 | 22,0 | 380 | 79,0 | 29,7 |
| V57 | 77,4 | 62,4 | 46,3 | 22,2 | 383 | 80,0 | 29,8 |
| V58 | 75,8 | 61,9 | 45,8 | 21,6 | 382 | 79,4 | 29,5 |
| V60 | 75,1 | 61,2 | 45,2 | 21,4 | 378 | 78,5 | 29,1 |
| V61 | 74,8 | 60,9 | 45,0 | 21,5 | 371 | 77,3 | 28,8 |
| V62 | 75,7 | 61,7 | 45,7 | 21,7 | 376 | 78,4 | 29,2 |
| V63 | 74,7 | 61,2 | 44,8 | 21,2 | 371 | 77,5 | 28,7 |
| Reference value | 75,9 | 61,6 | 45,7 | 21,7 | 378 | 78,8 | 29,3 |
| SD | 1,2 | 0,8 | 0,7 | 0,4 | 5,9 | 1,2 | 0,5 |
| RSD, % | 1,5 | 1,3 | 1,5 | 1,8 | 1,6 | 1,5 | 1,8 |

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

| Laboratory | Filter no. | Correction factor | Reported results | | | | | | | Corrected results | | | | | | | | |
|---------------------|------------|-------------------|------------------|-------|------|------|-------|-------|--------|-------------------|-------|------|------|-------|-------|--------|------|-------|
| | | | Be | Cd | Co | Mo | Ni | Pb | Zn | Be | Cd | Co | Mo | Ni | Pb | Zn | | |
| | | µg | µg | µg | µg | µg | µg | µg | µg | µg | µg | µg | µg | µg | µg | µg | | |
| Analyselaboratoriet | C 7 | 0,997 | | 15,7 | 42,8 | | | 72,0 | 46,2 | 264,4 | | | 15,7 | 42,9 | | 72,2 | 46,3 | 265,2 |
| | C 27 | 0,999 | | 15,8 | 42,8 | | | 71,5 | 45,5 | 266,5 | | | 15,8 | 42,8 | | 71,6 | 45,5 | 266,8 |
| Falconbridge | C 16 | 0,999 | 2,65 | 16,7 | 42,2 | 49,1 | 68,5 | 41,0 | 256 | 2,65 * | 16,7 | 42,2 | 49,1 | 68,6 | 41,0 | 256 | | |
| | C 40 | 1,001 | 2,65 | 16,7 | 42,1 | 49,0 | 69,0 | 41,0 | 256 | 2,65 * | 16,7 | 42,1 | 49,0 | 68,9 | 41,0 | 256 | | |
| HSL | C 18 | 0,999 | 1,68 | 17,2 | 43,3 | 39,7 | 68,7 | 43,7 | 255 | 1,68 | 17,2 | 43,3 | 39,7 | 68,8 | 43,7 | 255 | | |
| | C 46 | 1,000 | 1,68 | 17,7 | 44,5 | 40,7 | 70,7 | 44,4 | 260 | 1,68 | 17,7 | 44,5 | 40,7 | 70,7 | 44,4 | 260 | | |
| Inst. of Hygiene | C 12 | 0,997 | | 16,00 | | | 67,00 | 43,10 | | | 16,05 | | | 67,20 | 43,23 | | | |
| | C 36 | 0,998 | | 16,10 | | | 67,50 | 43,30 | | | 16,13 | | | 67,64 | 43,39 | | | |
| Kuopio | C 1 | 1,001 | | 17 | 40 | | 78 | 42 | 245 | | 17 | 40 | | 78 | 42 | 245 | | |
| | C 22 | 0,999 | | 17 | 40 | | 80 | 42 | 246 | | 17 | 40 | | 80 | 42 | 246 | | |
| Miljø-Kemi | C 9 | 1,001 | 1,67 | 18,0 | 43,2 | 45,3 | 73,9 | 46,9 | 279 | 1,67 | 18,0 | 43,2 | 45,3 | 73,8 | 46,9 | 279 | | |
| | C 30 | 0,999 | 1,70 | 16,0 | 42,7 | 44,4 | 72,4 | 44,6 | 256 | 1,70 | 16,0 | 42,7 | 44,4 | 72,5 | 44,6 | 256 | | |
| Molab as | C 5 | 0,995 | | 15,9 | 41,5 | | 64,7 | 49,1 | 233 | | 16,0 | 41,7 | | 65,0 | 49,3 | 234 | | |
| | C 44 | 1,002 | | 15,9 | 41,5 | | 65,0 | 44,1 | 231 | | 15,9 | 41,4 | | 64,9 | 44,0 | 231 | | |
| NIOH, Denmark | C 14 | 1,005 | | 16,57 | | | | 36,85 | 265,33 | | 16,49 | | | | 36,67 | 264,01 | | |
| | C 43 | 0,999 | | 16,59 | | | | 40,25 | 264,15 | | 16,61 | | | | 40,29 | 264,41 | | |
| Sero AS | C 20 | 0,998 | 1,72 | 16,7 | 43,8 | 44,1 | 70,4 | 43,1 | 256 | 1,72 | 16,7 | 43,9 | 44,2 | 70,5 | 43,2 | 257 | | |
| | C 47 | 0,999 | 1,71 | 16,8 | 43,5 | 43,5 | 69,5 | 44,3 | 255 | 1,71 | 16,8 | 43,5 | 43,5 | 69,6 | 44,3 | 255 | | |
| SGAB Analytica | C 13 | 0,998 | 1,69 | 16,8 | 43,5 | 42,0 | 68,4 | 41,7 | 262 | 1,69 | 16,8 | 43,6 | 42,1 | 68,5 | 41,8 | 263 | | |
| | C 42 | 0,998 | 1,72 | 17,0 | 44,4 | 42,7 | 69,7 | 44,0 | 268 | 1,72 | 17,0 | 44,5 | 42,8 | 69,8 | 44,1 | 269 | | |
| Tinfos | C 10 | 0,999 | 1,7 | 17,5 | 44,0 | | 73,0 | 44,0 | 265 | 1,7 | 17,5 | 44,0 | | 73,1 | 44,0 | 265 | | |
| | C 41 | 0,999 | 1,7 | 17,5 | 43,0 | | 73,0 | 42,5 | 265 | 1,7 | 17,5 | 43,0 | | 73,1 | 42,5 | 265 | | |
| West Lab | C 26 | 0,999 | | 17 | 42 | 42 | 67 | 42 | 260 | | 17 | 42 | 42 | 67 | 42 | 260 | | |
| | C 38 | 0,996 | | 17 | 43 | 43 | 68 | 41 | 260 | | 17 | 43 | 43 | 68 | 41 | 261 | | |
| Reference value | | | | | | | | | 1,7 | 16,9 | 42,3 | 42,7 | 68,4 | 42,0 | 256 | | | |
| Uncertainty, µg | | | | | | | | | 0,01 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 2 | | | |
| Average | | | | | | | | | 1,7 | 16,7 | 42,7 | 43,8 | 70,4 | 43,2 | 258 | | | |
| SD, µg | | | | | | | | | 0,02 | 0,62 | 1,27 | 2,88 | 3,72 | 2,51 | 11,0 | | | |
| RSD, % | | | | | | | | | 1,1 | 3,7 | 3,0 | 6,6 | 5,3 | 5,8 | 4,3 | | | |

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

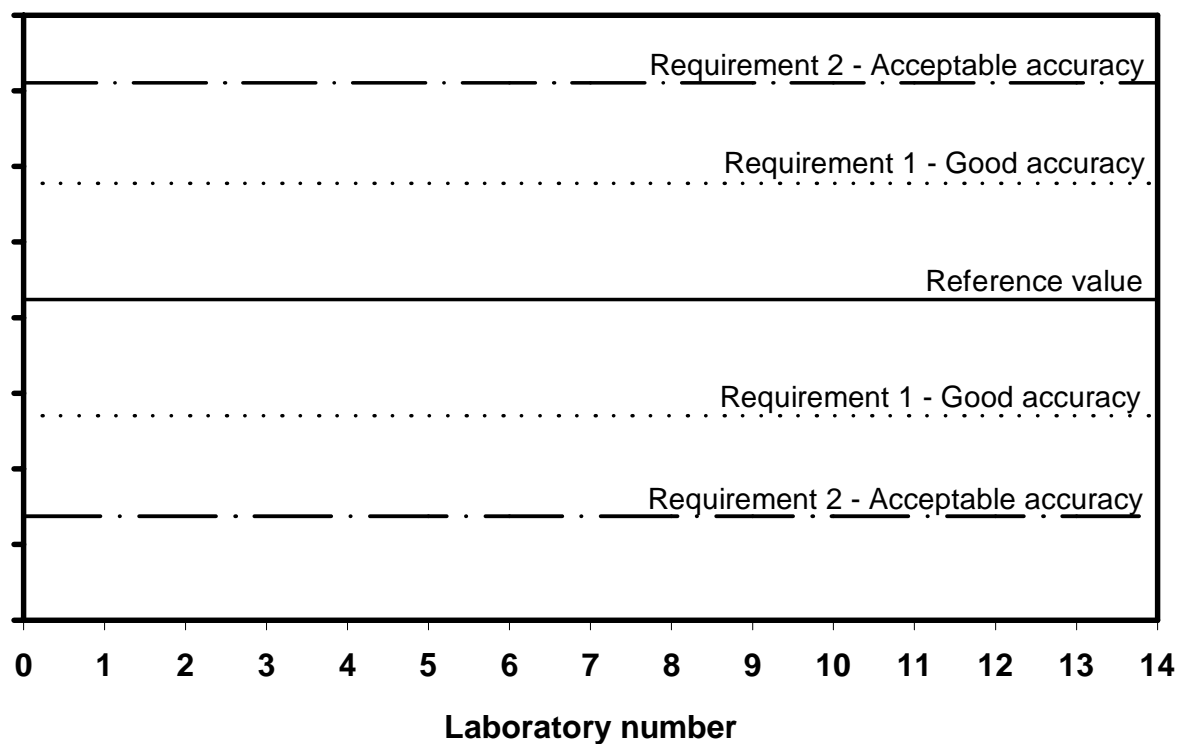
Table 4. Results reported by the participating laboratories, Series V - Welding fume filters

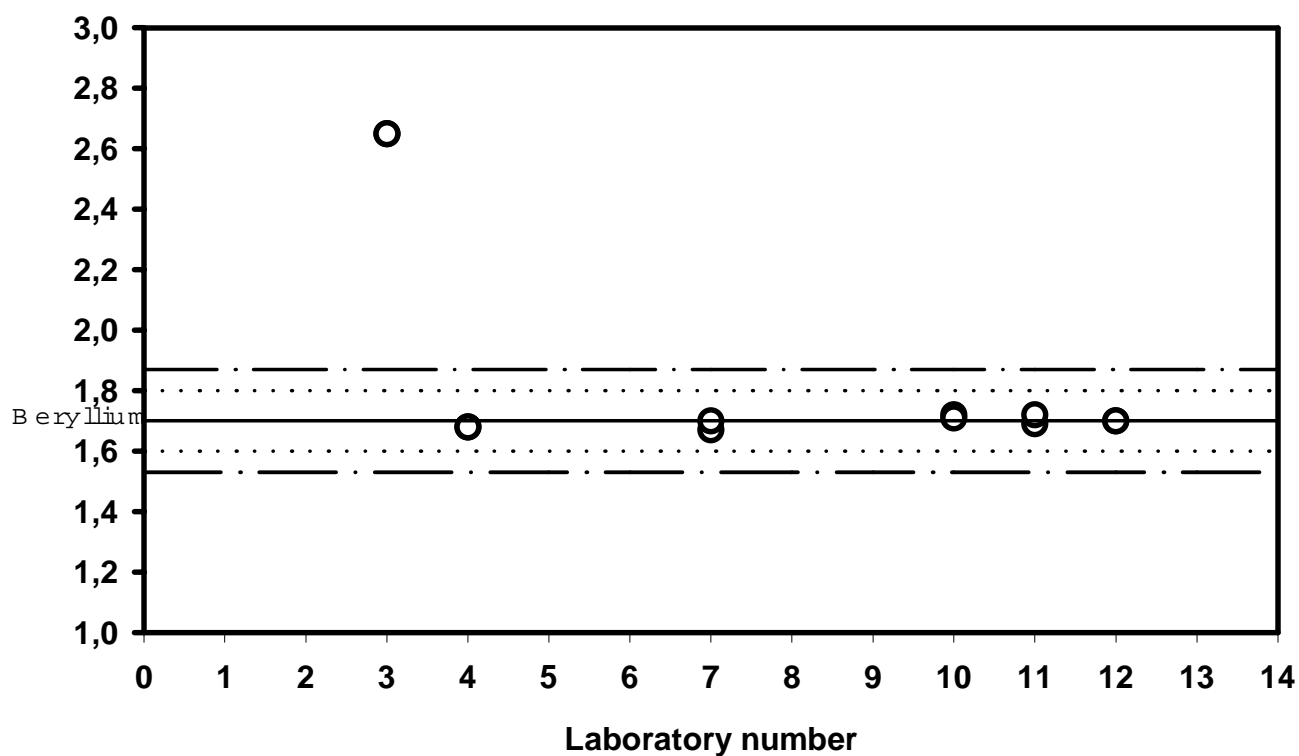
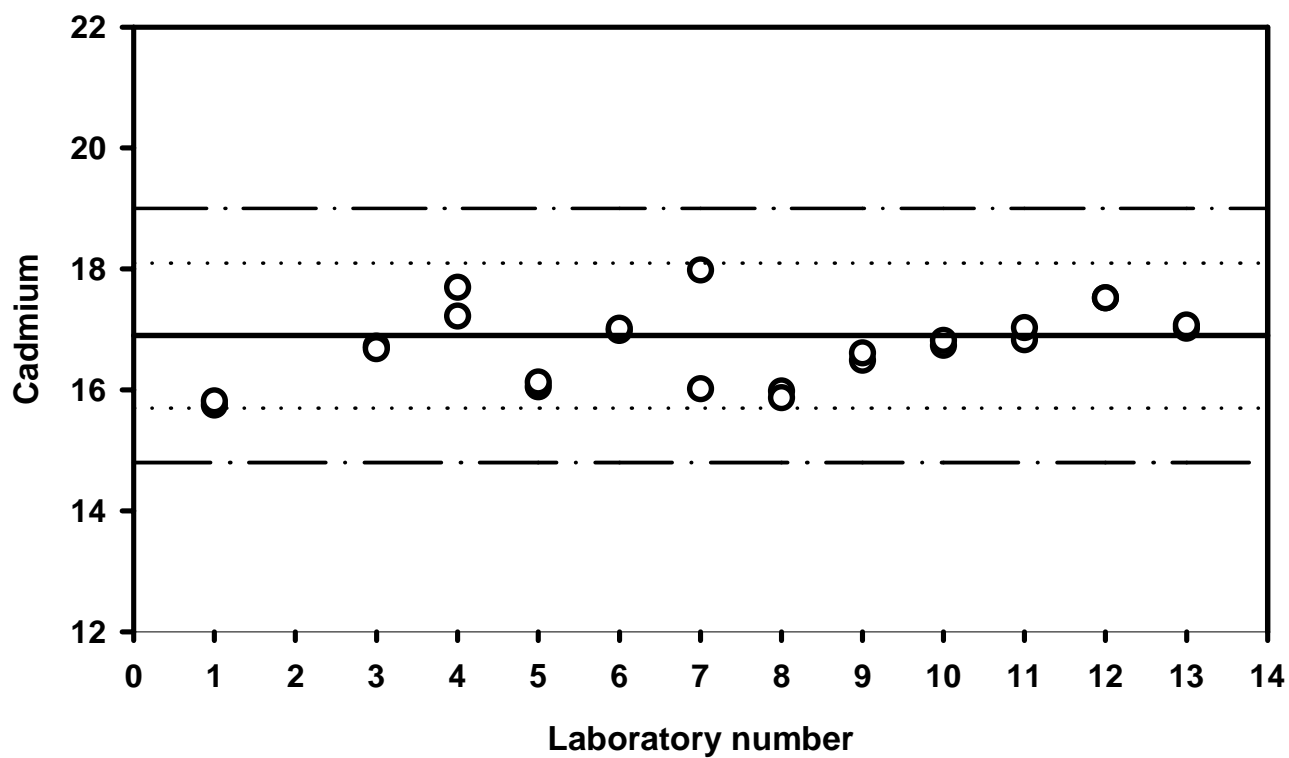
| Laboratory | Filter no. | Total mass mg | Ag µg | Al µg | Cr µg | Cu µg | Fe µg | Mn µg | Ti µg |
|------------------------|------------|------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Analyselaboratoriet | V10 | 4,80 | | 535 * | 46,3 | 21,2 | 412,0 | 76,8 | |
| | V14 | 4,79 | | 523 * | 47,8 | 21,9 | 415,5 | 76,3 | |
| Elkem Bremanger | V 8 | 4,9 | | | | | | | |
| | V 39 | 4,6 | | | | | | | |
| Falconbridge | V 11 | 5,4 | 67,5 | 46,4 | 40,0 | 21,1 | 362 | 75,5 | 27,0 |
| | V 28 | 5,4 | 74,0 | 46,1 | 41,4 | 22,4 | 377 | 78,5 | 28,1 |
| HSL | V 19 | 4,84 | 17,2 * | 59,2 | 49,1 | 21,5 | 408 | 83,7 | 31,5 |
| | V 25 | 4,80 | 16,4 * | 57,9 | 47,6 | 20,8 | 395 | 81,2 | 30,7 |
| Inst. of Hygiene | V 21 | 4,82 | 12,8 * | 78,25 | 46,00 | 54,6 * | 300,00 | 83,50 | |
| | V 38 | 4,60 | 12,5 * | 74,25 | 47,00 | 53,4 * | 287,00 | 82,00 | |
| Kuopio | V 2 | | | 69 | 40 | 21 | 369 | 66 | |
| | V 45 | | | 69 | 40 | 21 | 356 | 64 | |
| Miljø-Kemi | V 22 | 4,65 | | 53,4 | 48,7 | 22,2 | 394 | 83,3 | 26,7 |
| | V 30 | 4,89 | | 54,0 | 51,0 | 23,7 | 398 | 85,8 | 28,3 |
| Molab as | V 20 | 4,65 | | 58,5 | 46,8 | 21,6 | 370 | 74,6 | |
| | V 37 | 4,69 | | 60,5 | 44,1 | 21,7 | 385 | 74,0 | |
| NIOH, Denmark | V 17 | | | | 45,61 | | 389,38 | 76,52 | |
| | V 36 | | | | 45,29 | | 387,76 | 76,54 | |
| Sero AS | V 1 | 4,75 | 78,9 | 62,6 | 45,8 | 21,8 | 376 | 77,6 | 29,9 |
| | V 23 | 4,75 | 76,6 | 61,4 | 46,0 | 22,0 | 377 | 78,0 | 30,2 |
| SGAB Analytica | V 12 | 4,75 | 2,24 * | 59,0 | 46,2 | 19,3 | 396 | 77,4 | 30,3 |
| | V 42 | 4,69 | 1,52 * | 57,3 | 44,4 | 19,3 | 387 | 75,4 | 29,2 |
| Tinfos | V 14 | 4,79 | 80,5 | 60,0 | 45,5 | 22,5 | 394 | 81,5 | 25,0 |
| | V 47 | 4,90 | 83,0 | 63,0 | 46,5 | 23,0 | 398 | 84,0 | 25,0 |
| West Lab | V 29 | 4,60 | 76 | 45 | 43 | 21 | 360 | 75 | 25 |
| | V 44 | 4,50 | 71 | 50 | 40 | 22 | 350 | 72 | 24 |
| Reference value | | 4,72 | 77,7 | 57,3 | 44,8 | 21,4 | 382 | 77,4 | 27,3 |
| Average | | 4,80 | 75,9 | 59,2 | 45,2 | 21,6 | 377 | 77,5 | 27,9 |
| SD, µg | | 0,2 | 5,1 | 8,9 | 3,1 | 1,1 | 31,0 | 5,3 | 2,5 |
| RSD, % | | 4,6 | 6,7 | 15,0 | 6,8 | 4,9 | 8,2 | 6,9 | 8,9 |

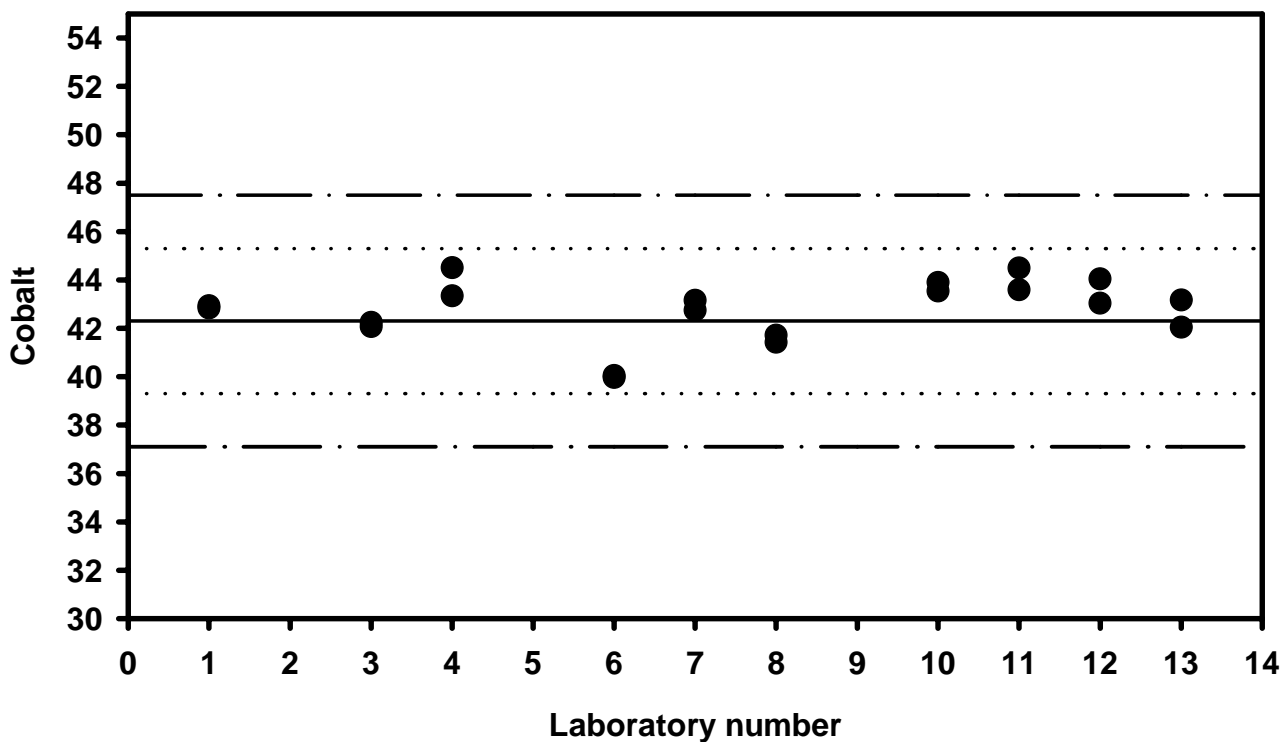
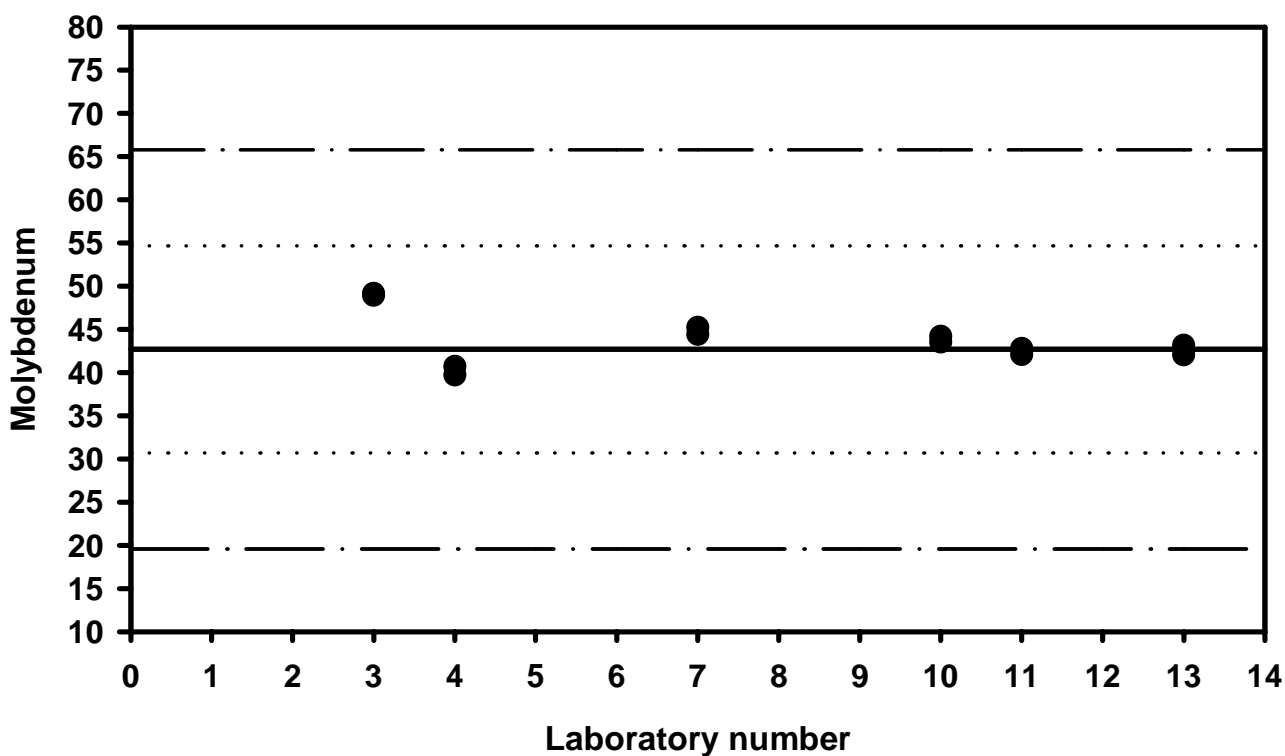
*: Outlier, result rejected after applying Grafs and Hennings method for evaluation of extreme analytical results. A significance level of 95 % was used.

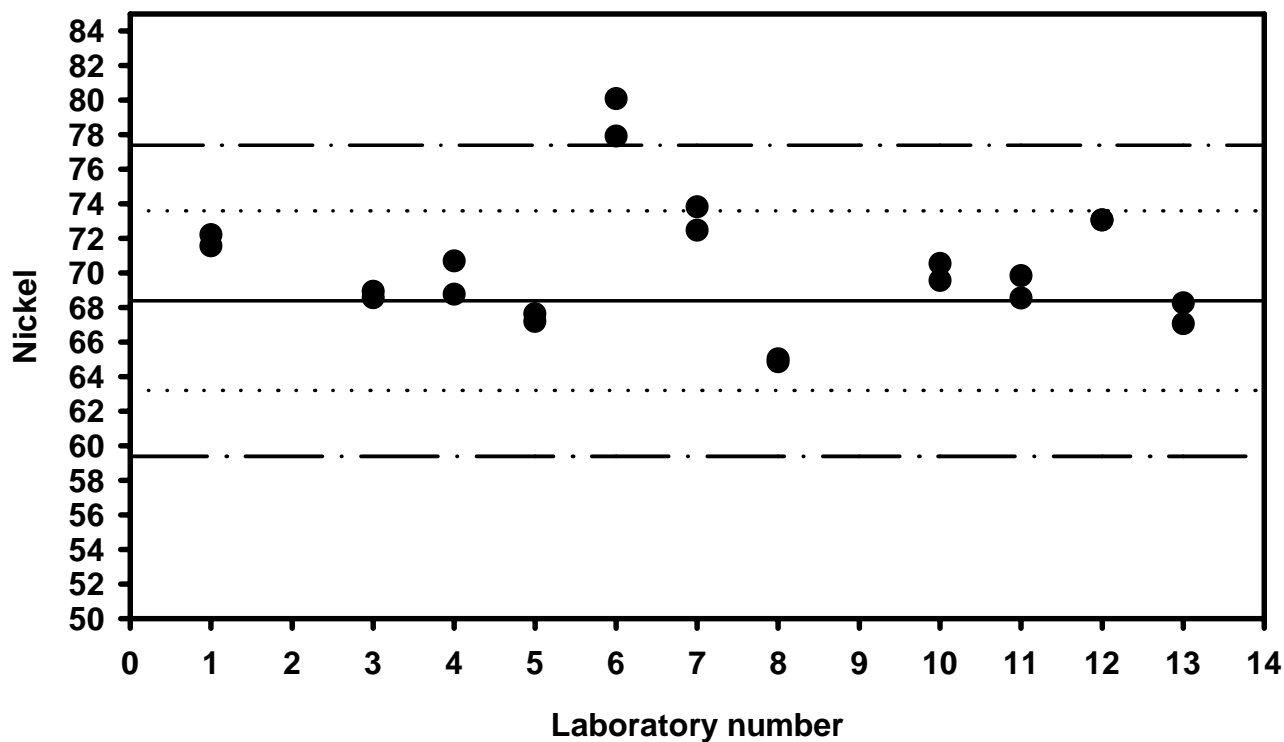
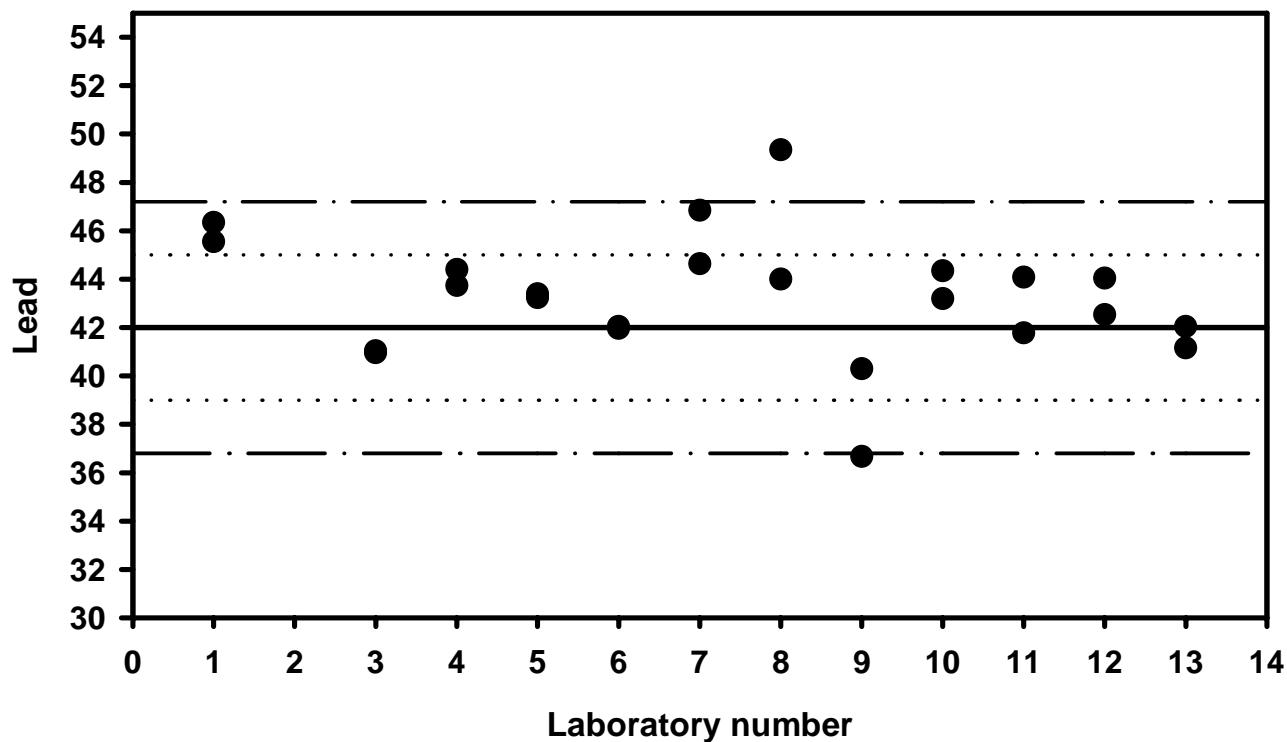
APPENDIX 2

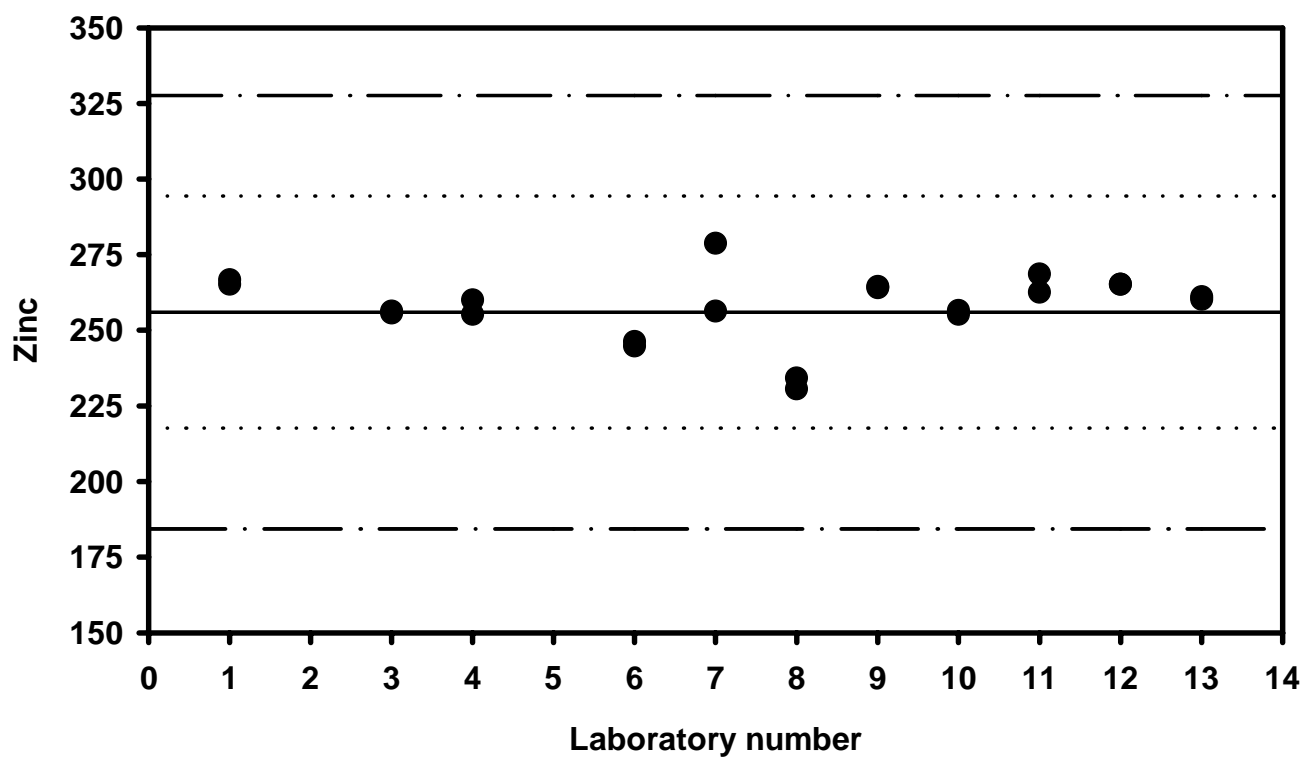
The following figure is used to illustrate the reported values from each laboratory. The solid line represents the reference value, while the dotted lines indicate the requirements for «good» and «acceptable» results.



Beryllium - Series CReference value: 1,7 μg Laboratory average: 1,7 μg **Cadmium - Series C**Reference value: 16,9 μg Laboratory average: 16,9 μg 

Co - Series CReference value: 42,3 μg Laboratory average: 42,7 μg **Molybdenum - Series C**Reference value: 42,7 μg Laboratory average: 43,8 μg 

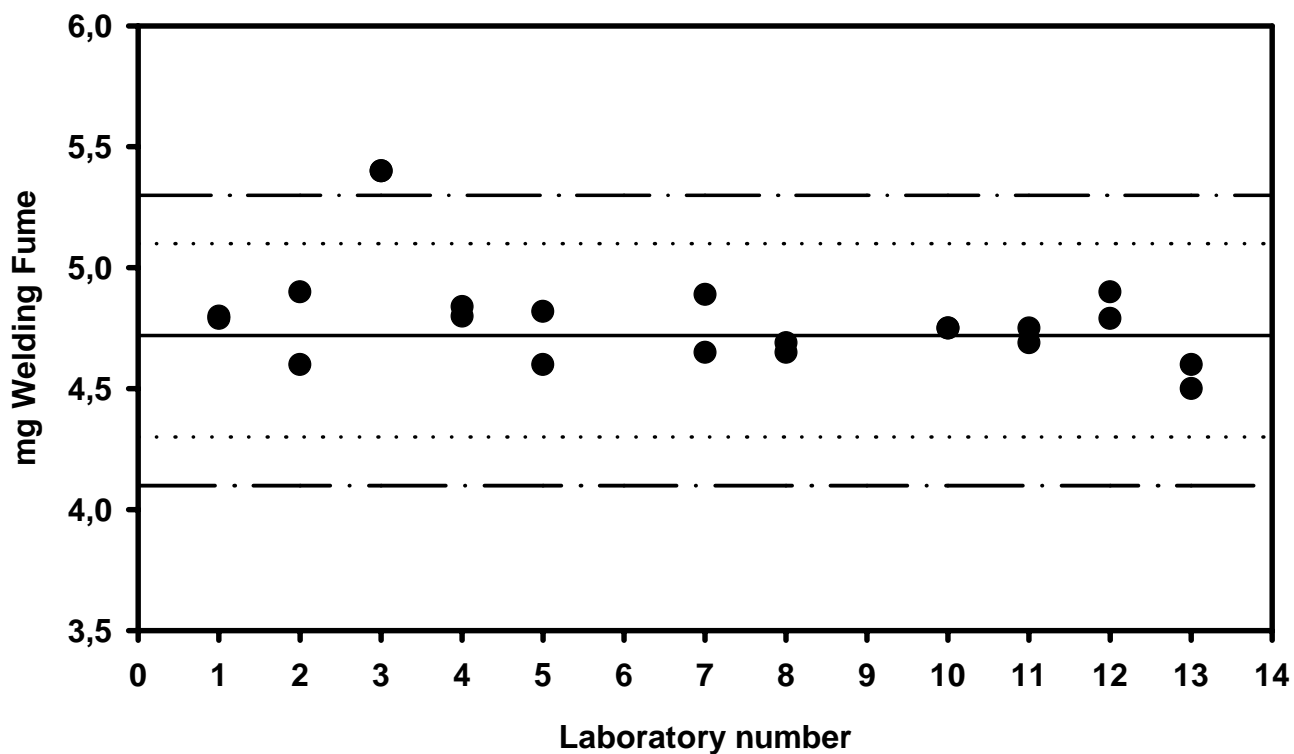
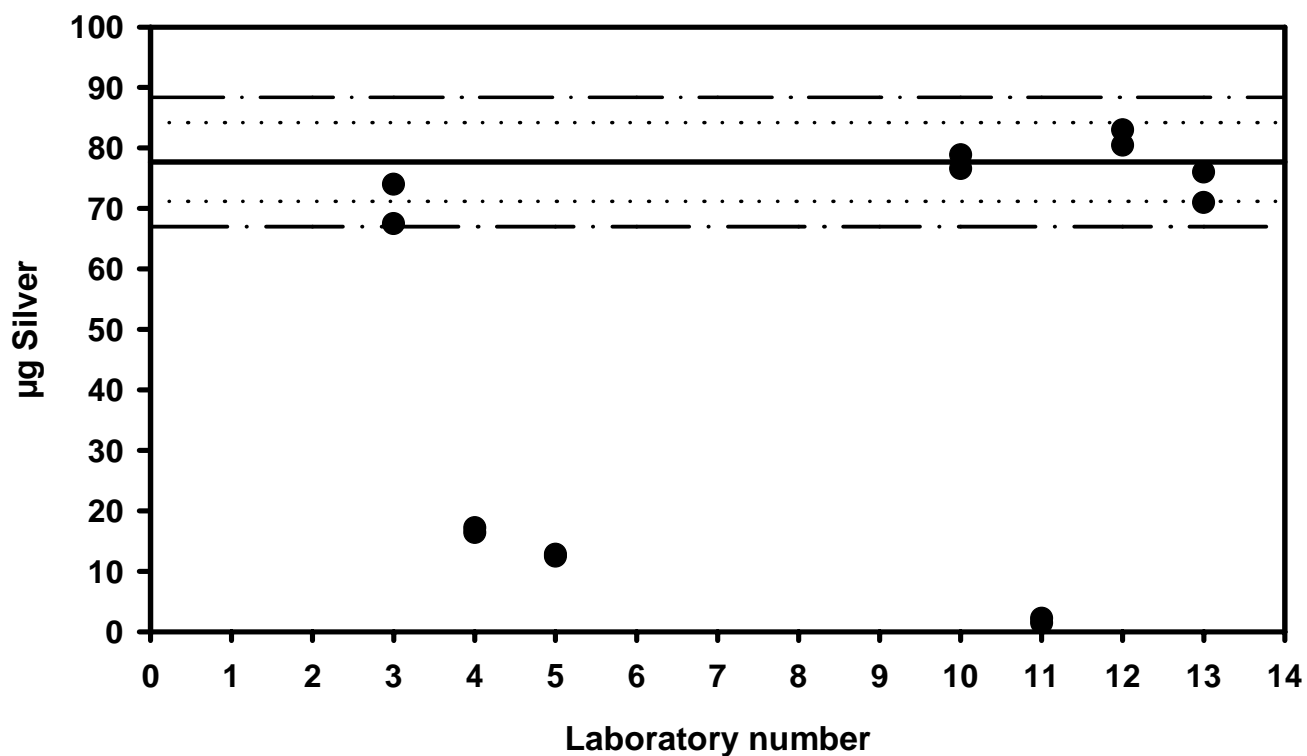
Nickel - Series CReference value: 68,4 μg Laboratory average: 70,4 μg **Lead - Series C**Reference value: 42,0 μg Laboratory average: 43,2 μg 

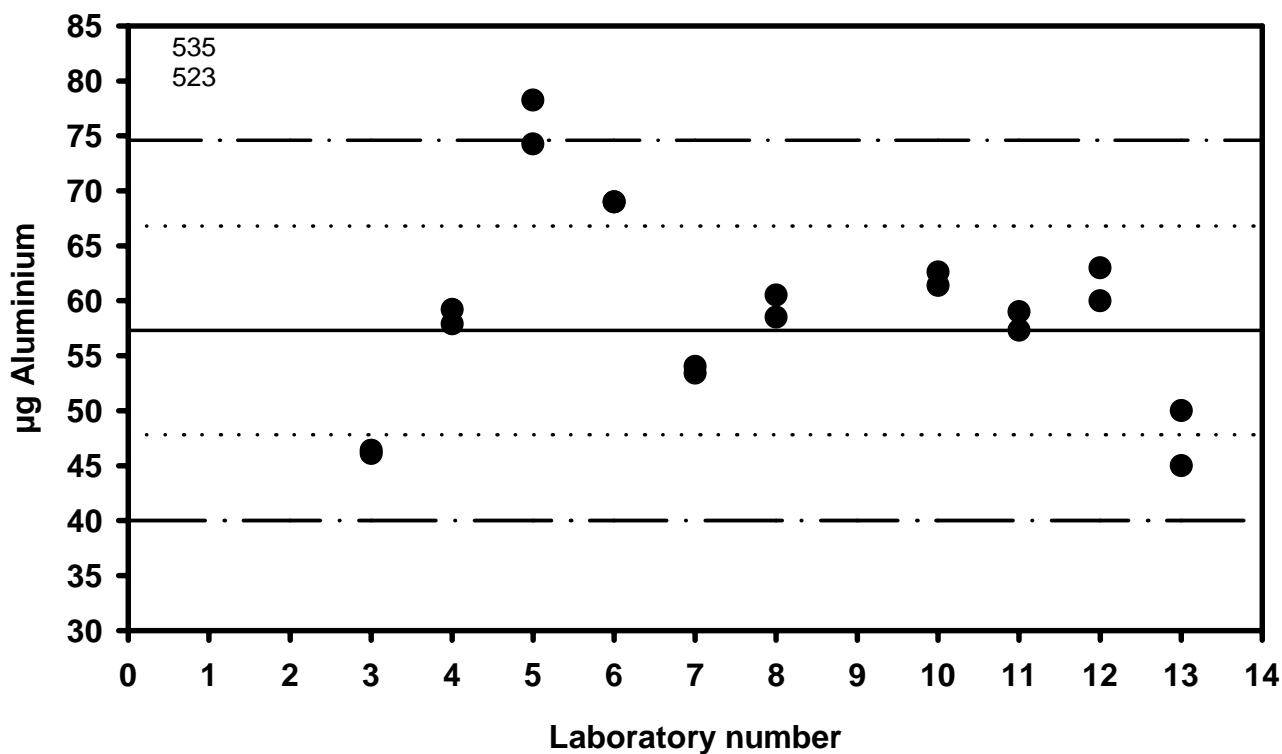
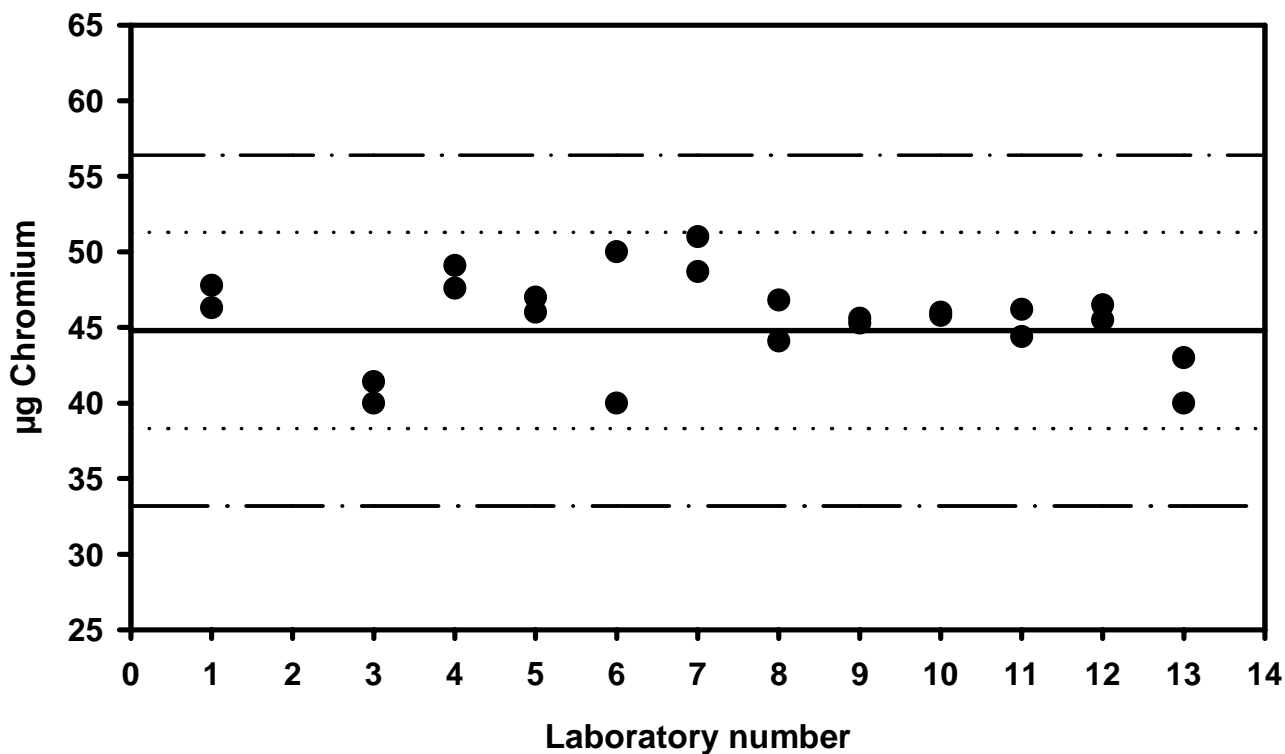
Zinc - Series CReference value: 256 μg Laboratory average: 258 μg 

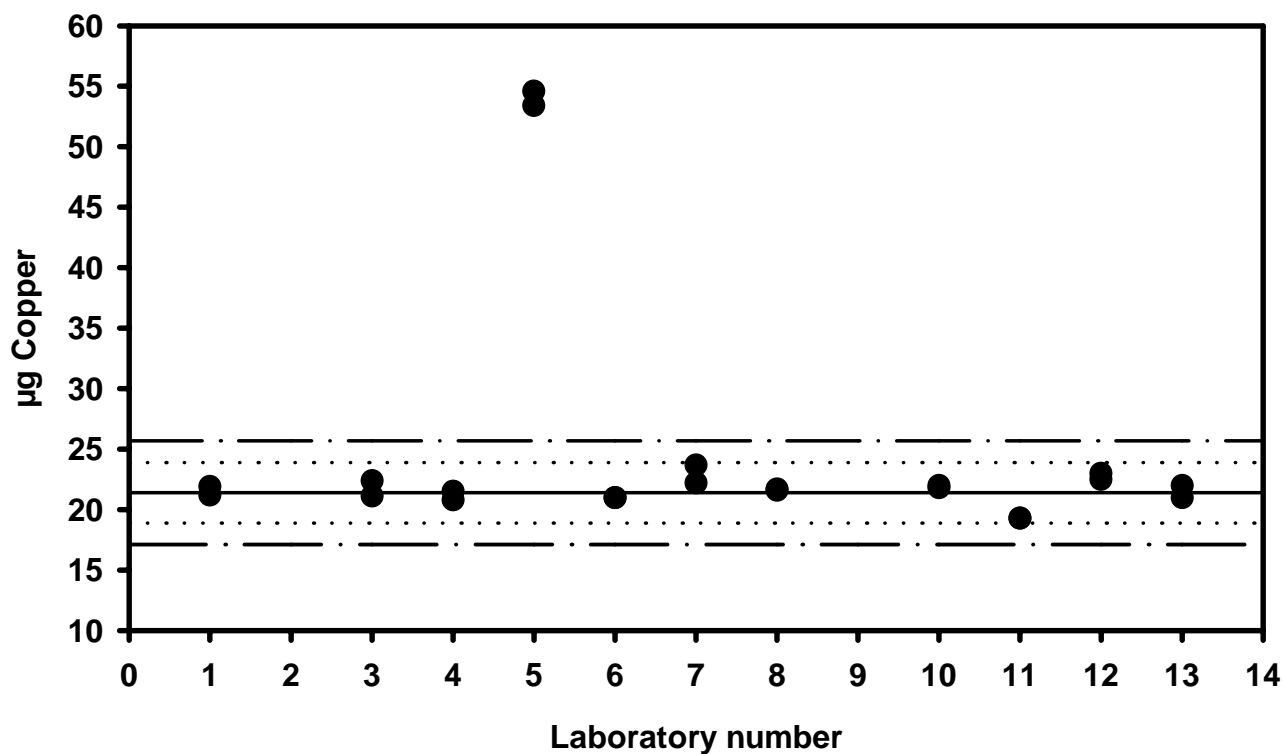
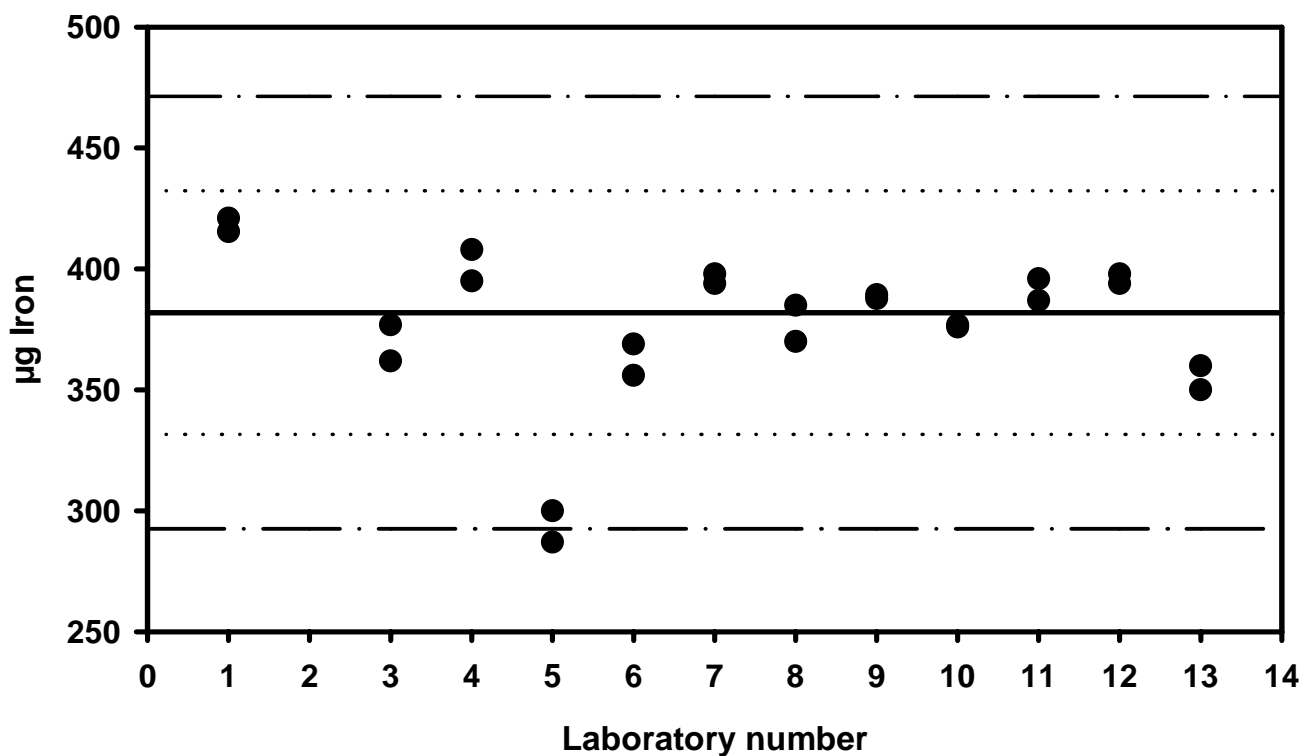
Total Mass - Series V

Reference value: 4,7 mg

Laboratory average: 4,8 mg

**Silver - Series V**Reference value: 77,7 μg Laboratory average: 75,9 μg 

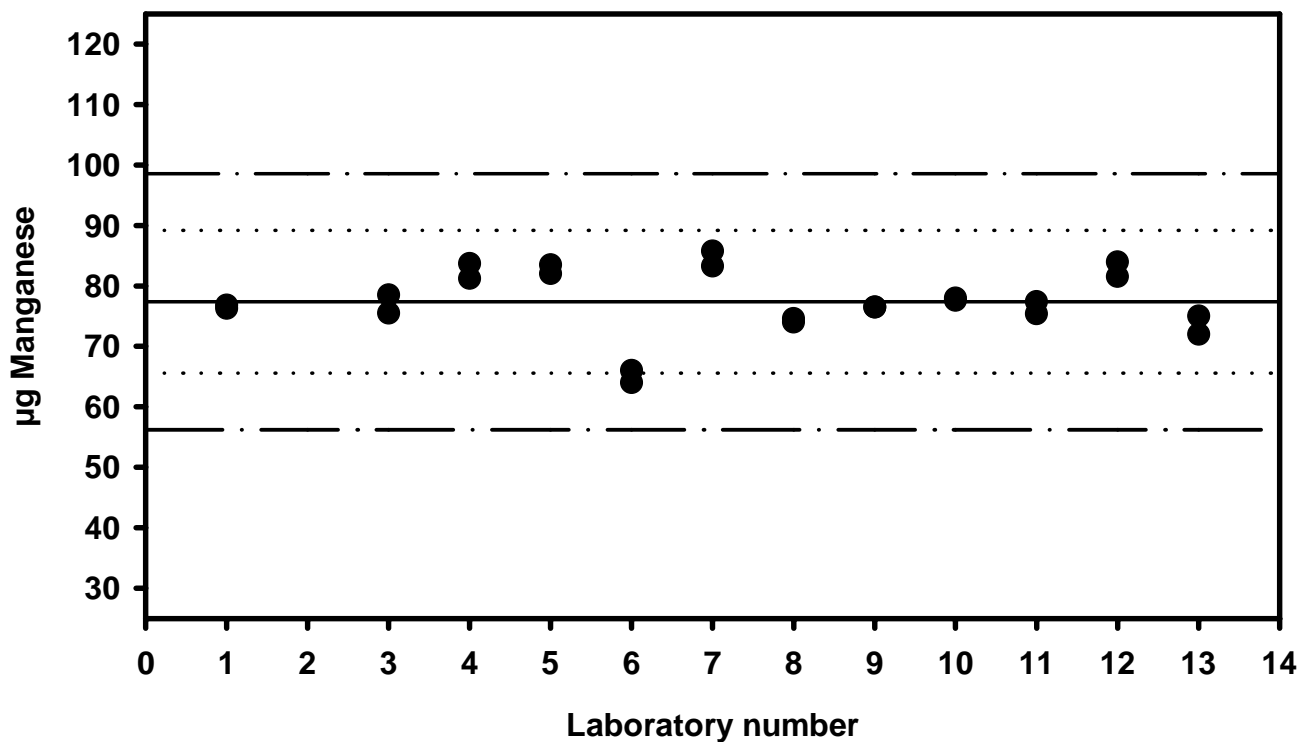
Aluminium - Series VReference value: 57,3 μg Laboratory average: 59,2 μg **Chromium - Series V**Reference value: 44,8 μg Laboratory average: 45,2 μg 

Copper - Series VReference value: 21,4 μg Laboratory average: 21,6 μg **Iron - Series V**Reference value: 382 μg Laboratory average: 377 μg 

Manganese - Series V

Reference value: 77,4 µg

Laboratory average: 77,5 µg

**Titanium - Series V**

Reference value: 27,3 µg

Laboratory average: 27,9 µg

