INSTRUMENTAL BLANK SAMPLES ASSESSED THROUGH SHORT RUN CONTROL CHARTS

Andreia Matos [1], Andreia Rego [2], *Isabel Castanheira* [2], *Ana Sofia Matos* [1]

[1] UNIDEMI, Departamento de Engenharia Mecânica e Industrial, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal, asvm@fct.unl.pt
[2] Department of Food and Nutrition, National Institute of Health Dr. Ricardo Jorge, Av. Padre Cruz, 1649-016 Lisbon, Portugal, Isabel.castanheira@insa.min-saude.pt

Abstract – This paper presents a study where Statistical Process Control (SPC) are used as an internal quality control tool to monitor and assess the stability of instrumental blank samples for inorganic arsenic determination by inductively coupled plasma mass spectrometry (ICP-MS). The use of Short Run control charts combined with process capability analysis revealed to be a suitable tool allowing to detect possible reagent or instrumental contaminations in a daily base.

Keywords: internal quality control, instrumental blank samples, ICP-MS, Short Run control chart, process capability

1. INTRODUCTION

The Internal Quality Control (IQC) is a key activity in a Quality Assurance system [1]. The IQC involves a continuous and critical assessment of own analytical methods and work routines, in an analytical chemistry laboratory, with the main purpose of continuously monitoring the developed methodologies and assess the reliability of the results [2, 3].

The blank samples are an excellent internal quality control tool, that allows not only evaluating and monitoring the quality of reagents and analytical processes, as well as to estimate the limit of detection (LOD) and the limit of quantification (LOQ) for the trace elements analysed by ICP-MS [4].

The use of control charts allow a simple way to check the accuracy of the analytical methods in a daily routine [5]. Particularly, the Short Run control charts, based on the Quesenberry Q-statistics, are very useful when there are not enough data to estimate process parameters or when the sample size is variable in time [6][7].

The main purpose of this paper is to develop a joint application using the main SPC concepts, such as control charts and process capability analysis. An intra- and inter-day instrumental blank samples control scheme, using control charts based on Quesenberry Q-statistics, was applied to inorganic arsenic to monitor and assess statistical consistence of blank data analysed by ICP-MS [6]. Control charts combined with process capability analysis will constitute a novelty study that will allows to evaluate the in used instrumental LOQ values for inorganic arsenic and establish a new limit.

2. MATERIALS AND METHODS

2.1. Samples preparation

All samples and standard preparation steps were carried out in clean room facilities. Blank samples were prepared on a daily basis by preparing a solution of 2% HNO_3 (V/V) with Milli-Q water (18 µΩ) (Q-POD Millipore, Interface, Portugal). A nitric acid solution with 2% concentration was used for working standards and as rinsing solution between samples for the ICP-MS. Internal standards were added to all samples and working standards, in order to correct instrumental drift.

2.2. Reagents

All solutions were prepared using ultrapure water. Nitric acid p.a. (65% v/v) was previously purified by sub-boiling distillation using a SubPur apparatus (Milestone, Unicam, Portugal). Hydrogen peroxide solutions acquired were of ultrapure grade. For the calibration curve working standard solutions were prepared from multi-element high purity ICP stock standard containing 100 mg/L of arsenic. IQC standard were prepared using the multi-element standard solution, high purity ICP 100 mg/L, from Merck. According to the matrix under analysis and internal standards were chosen

between Germanium (1000 mg.L^{-1}; Inorganic Ventures), Yttrium and/or Indium (1000 mg.L^{-1}; Merck).

2.3. Instrumentation

Measurements were performed using a quadrupole ICP-MS (Thermo Elemental, X-series 2, UK). Further details of the instrumental settings are specified in table 1.

Table 1. ICP-MS operating conditions.

ICP-MS Thermo X series II	
Extraction	-113,7
Focus	10,0
Pole Bias	-0,1
Hexapole Bias	-3,0
Nebulizer flow rate (L min^{-1})	0,87
Forward Power (W)	1404
Cool gas flow rate (L min^{-1})	13,0
Auxiliary gas flow rate (L min^{-1})	0,90
Sampling Depth	120
Standard Resolution	135
High Resolution	150
Analogue Detector	1902
PC Detector	3353

The parameters were monitored daily for elementary stability and sensitivity, mass calibration and for the presence of oxides and doubly charged ions, and the above conditions optimized accordingly.

3. RESULTS AND DISCUSSION

One set of instrumental blank samples used to analyse inorganic arsenic through ICP-MS was collected during 2015. Non-consecutive days were considered, where only a single matrix was analysed in each day (sample size ranged from 6 to 19 observations). The following matrixes used in this study were: meat, fish, fruit, vegetables, cereals and composts.

3.1. Preliminary analysis

A graphical analysis, followed by an outlier study was performed, with no outliers identified. Two one-way Analysis of Variance (ANOVA) were applied. The first one is considered as a controllable factor of days (14 levels) and the second analyze the existence of possible differences between days with the same matrix (4 levels for cereals and 3 levels for fruit). The first ANOVA allowed to conclude significant differences between days ($p < 0.000$). Through, the last two ANOVAs, significantly differences between cereals were found ($p < 0.01$) but not between fruits ($p = 0.074$). These conclusions evidence the need to control and monitor blank samples intra-day and inter-day behavior in a routine basis. All ANOVA assumptions were checked against any violation conditions. For ANOVA between days and between cereals, homoscedasticity was violated, so a non-parametric approach was used (Kruskal-Wallis test).

All statistical analyses were performed using Statistica v.10 software (Statsoft Ibérica, Lisboa, Portugal).

3.2. Process Capability Analysis

To apply Short Run control charts, Q(X) and Q(MR) for intra-day control and Q($\overline{X}$) and Q(S^2) for inter-day control, the authors followed the methodology developed by Matos et al [6]. To enhance control charts efficiency an additional study based on capability analysis is proposed, using normalized capability indices.

The normalized capability indices were recorded at each time r on the *Q(X)* or $Q(\overline{X})$ chart. These indices are obtained for each j instant / day at time r by the equation (1), considering a unilateral specification. The process for the instant / day j is considered capable when it satisfies the condition $(Q_U)_j > 3$.

$$\left((Q_r)_U\right)_j = \left(\frac{USL - \mu_r}{k\,\sigma_r}\right)_j \qquad (1)$$

USL is the upper specification limit, given by LOQ, and k value is constant equal to 1.25 since the specifications is unilateral (1.33 for bilateral specifications). The values μ_r and σ_r for the instance / day j, are estimated by equations (2) and (3), respectively.

$$\hat{\mu}_r = \overline{X} \quad \text{or} \quad \hat{\mu}_r = \overline{\overline{X}}_r \qquad (2)$$

$$\hat{\sigma}_r = \frac{\overline{MR}_r}{d_2} \quad or \quad \frac{\overline{S}_r}{c_4} \qquad (3)$$

where equations (4) and (6) is for intra-day chart and (5) and (7) for inter-day control:

$$\overline{X}_r = \frac{1}{r}\left((r-1)\overline{X}_{r-1} + X_r\right), \quad r = 2,3,\ldots \qquad (4)$$

$$\overline{\overline{X}}_r = \frac{1}{r}\left((r-1)\,\overline{\overline{X}}_{r-1} + \overline{X}_r\right) \quad , \quad r = 2,3,\ldots \qquad (5)$$

$$\overline{MR}_r = \frac{1}{r}\left((r-1)\,\overline{MR}_{r-1} + MR_r\right) \quad , \quad r = 3,4,\ldots \qquad (6)$$

$$\overline{S}_r = \frac{1}{r}\left((r-1)\,\overline{S}_{r-1} + S_r\right) \quad , \quad r = 2,3,\ldots \qquad (7)$$

3.2. Intra-day control

The charts presented in Figures 1 and 2, for Q(X) and Q(MR) control charts respectively, allows to monitor instrumental blank samples behaviour and respective variability, in a daily base. To evaluate the distance of each blank to inorganic arsenic LOQ, weighted by the cumulative standard deviation, an upper capability index was used. As can be seen in Figures 1 and 2, no out-of-control occurrences were detected. However, Figure 1 evidences same days where situations of lack of capability occurred, namely in days 1, 4, 5, 11 and 14 ($Q_{Uj} < 3$). The remaining nine days the capability indices reach high values, ranged from 3.15 to 16.25, indicating an excellent performance against the established LOQ value.

3.3. Inter-day control

Similarly to intra-day control, Q($\overline{\overline{X}}$) and Q(S^2) control charts were applied to control the mean and the variability along the days, with $\overline{\overline{X}}$ and $\overline{S^2}$ as sample mean and sample variance, respectively. Upper capability indices were calculated and reported in Figure 3, using equations (2), (3), (5) and (7). In Figure 4 the Q(S^2) chart is presented.

Two out-of-control situations occur at day 4th and 5th in Q($\overline{\overline{X}}$) control chart (Figure 3). This situation may suggests the occurrence of changes in experimental conditions which can be related to the effect of temperature on equipment performance. The lack of capability in days 4th and 5th presented in Figure 1 can also justify these two out-of-controls.

Similar to intra-day control, the upper capability indices also show high values, once more pointing for an excellent performance with instrumental blank samples for inorganic arsenic.

5. CONCLUSIONS

The present study introduced an important upgrade to the methodology developed by Matos et al [6], with the inclusion of upper capability indices. This new joint approach allowed to improve considerable the efficacy and efficiency of the instrumental blank samples assessment along the day, in order to detect trends or even possible contaminations and act effectively whenever necessary. In a daily routine, this joint approach reveals to be a powerful and a pro-active tool which enables the laboratory to monitor the instrumental blanks statistical stability as well as to assess the ICP-MS performance, according to experimental conditions.

REFERENCES

[1] I. Taverniers, M. De Loose, and E. Van Bockstaele, “Trends in quality in the analytical laboratory. II. Analytical method validation and quality assurance,” *Trends Anal. Chem.*, vol. 23, no. 8, pp. 535–552, 2004.

[2] H. Hovind, B. Magnusson, M. Krysell, U. Lund, and I. Mäkinen, “Internal Quality Control - Handbook for Chemical Laboratories,” Oslo, Noruega, 2011.

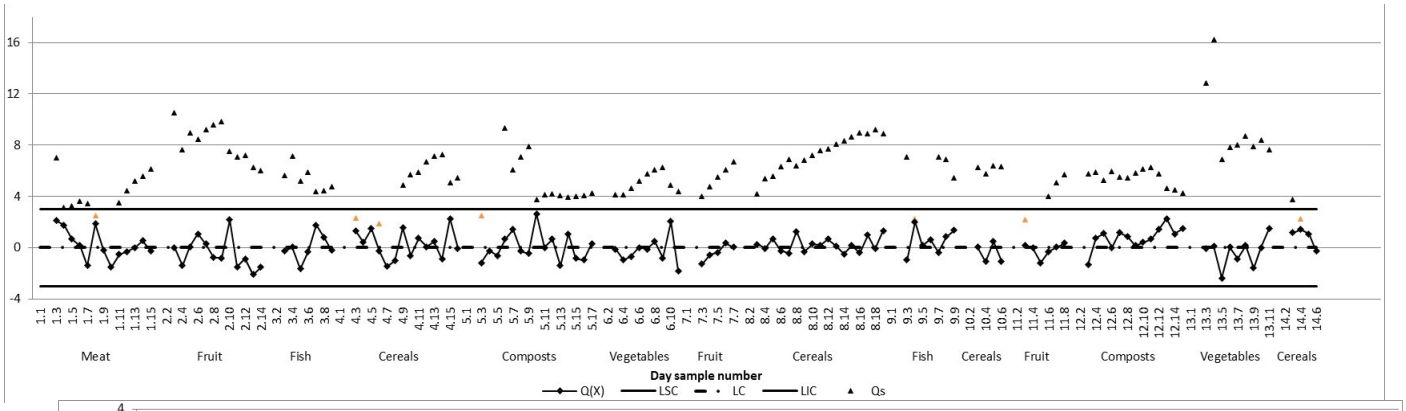
[3] F. Centrich, T. Subirana, M. Granados, and R. Companyó, “Practical Quality Control: the Experiences of a Public Health Laboratory,” in *Modern Approaches To Quality Control*, Rijeka, Croácia: InTech, 2011, pp. 415–438.

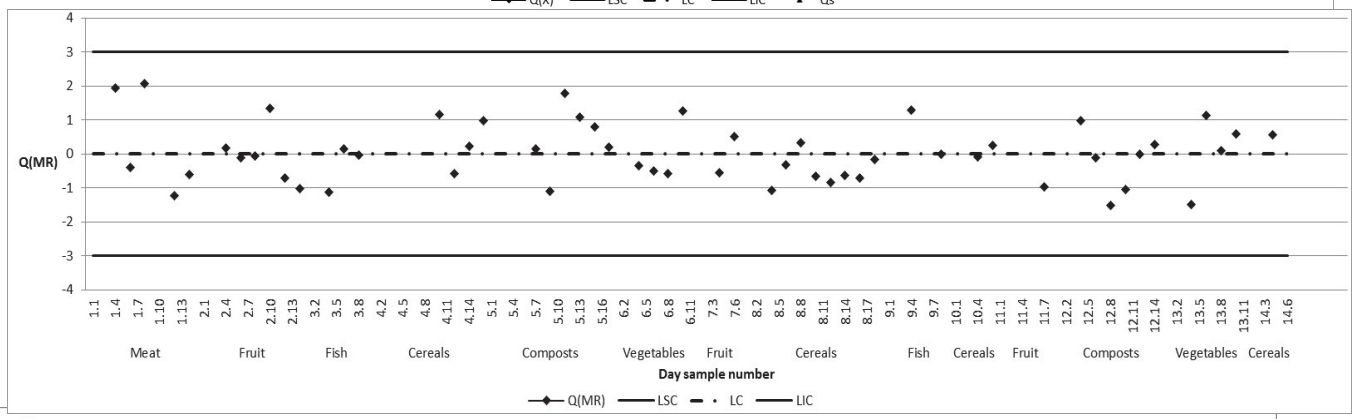
[4] CITAC/EURACHEM, *Eurachem Guide: The Fitness for Purpose of Analytical Methods – A Laboratory Guide to Method Validation and Related Topics,*. 2014.

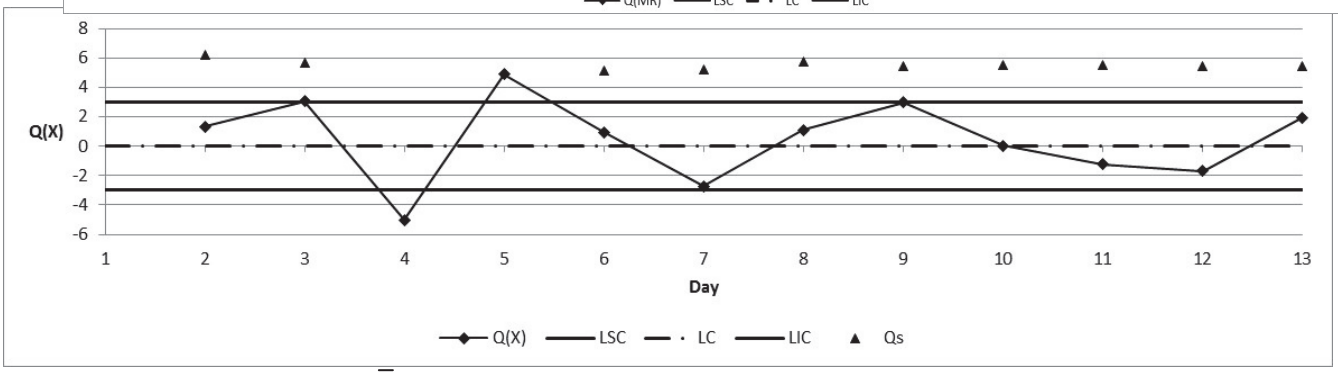
[5] M. Thompson and B. Magnusson, “Methodology in internal quality control of chemical analysis,” *Accredit. Qual. Assur.*, vol. 18, pp. 271–278, 2013.

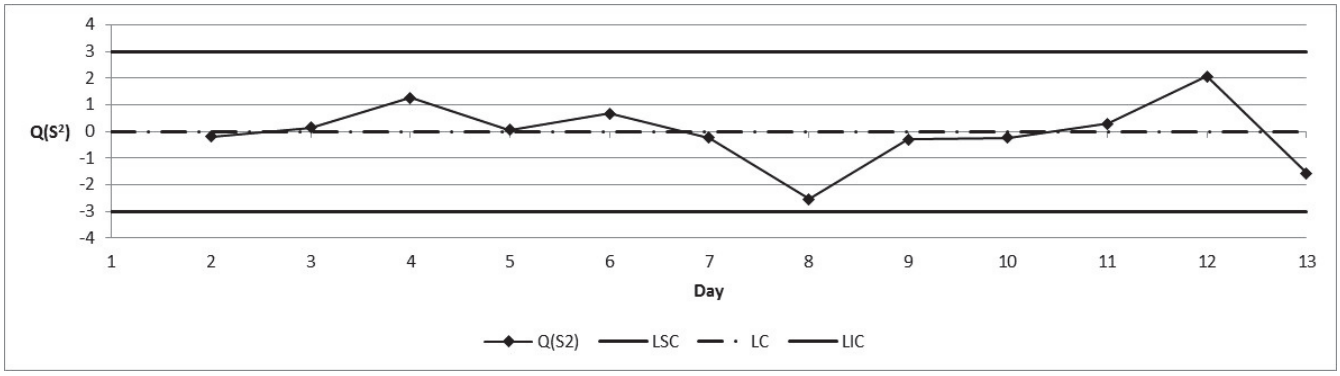
[6] A. S. Matos, J. G. Requeijo, I. Coelho, S. Gueifão, and I. Castanheira, “Short run control charts as an internal quality control tool,” *XXI IMEKO World Congr. "Measurement Res. Ind.*, 2015.

[7] C. P. Quesenberry, *SPC Methods for Quality Improvement*, John Wiley & Sons, New York, 1997.


Meat
Fruit
Fish
Cereals
Composts
Vegetables
Fruit
Cereals
Fish
Cereals
Fruit
Composts
Vegetables
Cereals
Day sample number
Q(X)
LSC
LC
LIC
Qs


Q(MR)
Meat
Fruit
Fish
Cereals
Composts
Vegetables
Fruit
Cereals
Fish
Cereals
Fruit
Composts
Vegetables
Cereals
Day sample number
Q(MR)
LSC
LC
LIC


Q(X)
Day
Q(X)
LSC
LC
LIC
Qs


Q(S²)
Day
Q(S2)
LSC
LC
LIC