

The Spanish external quality assessment scheme for lead in blood

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Summary. - In 1985 the Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT) established the "Programa Interlaboratorios de Control de Calidad de Plomo en Sangre (PICC-PbS)". The operation of this scheme is explained, criteria for evaluation of laboratory performance are defined and some results obtained are reviewed.

Key words: lead, blood, external quality assessment, Spain.

Riassunto (*Il programma spagnolo di valutazione esterna di qualità per la determinazione del piombo nel sangue*). - Nel 1985 l'Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT) ha promosso il "Programa Interlaboratorios de Control de Calidad de Plomo en Sangre (PICC-PbS)". Vengono descritte le procedure operative dello schema, i criteri per la valutazione delle prestazioni dei laboratori e i risultati ottenuti.

Parole chiave: piombo, sangue, valutazione esterna di qualità, Spagna.

Introduction

Quality assurance has been a subject of particular interest for the Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT). To this aim, INSHT implemented an external quality assessment scheme (EQAS), now available for any laboratory, called "Programa Interlaboratorios de Control de Calidad (PICC)". The programme includes a series of single schemes for different elements and matrices: PICC-PbS (lead in blood), PICC-HgU (mercury in urine), PICC-VO (organic vapours), PICC-FA (asbestos fibres) and PICC-MET (metals in filters).

The PICC-PbS was the first EQAS that INSHT established in Spain to test the proficiency of laboratories undertaking analyses in occupational hygiene and medicine.

The determination of the concentration of lead in blood along with several other indicators is required by the Spanish legislation to evaluate the level of exposure to lead at the workplace.

This parameter is decisive when establishing the necessary administrative, medical and technical measures in factories. Given the importance of decisions based on this parameter, the Spanish regulation on the prevention of risk from lead exposure at work [1] stated that analytical determinations of lead in blood should have a reliability of $\pm 15\%$ (or $\pm 6 \mu\text{g/dl}$ for concentrations lower than $40 \mu\text{g/dl}$).

It was therefore necessary to encourage the development of quality assurance procedures to ensure the reliability of analytical results and so the PICC-PbS

was created to assist laboratories carrying out analyses of lead in blood in assessing the accuracy of their results and assuring their validity.

Status and aims

The PICC-PbS was designed as a proficiency testing scheme to provide laboratories with the means to:

- plan their quality assurance;
- detect trends;
- assess the performance of their analytical procedures.

After an experimental phase of three years the scheme started in 1985 with the participation of 47 laboratories. At the end of 1994 there were 79 participants, of whom 53% were Spanish, 4% Portuguese and the remaining 43% from Latin-American countries. The PICC-PbS is a voluntary scheme, open to any laboratory from any country. However, cultural and historical reasons have greatly influenced foreign participation. The financial support for the scheme is from the resources of INSHT and participation is free of charge.

At the moment, all participants use atomic absorption spectrometry. Electrothermal atomic absorption spectrometry is used by 61% of them and 39% use flame atomic absorption spectrometry. The field of activity of 58% of participants is occupational health and the remaining 42% includes hospital laboratories, universities and other work activities related with health, toxicology and environmental protection.

Operation of the PICC-PbS scheme

Preparation of samples

Human blood, obtained from a hospital blood bank and free from infectious-contagious factors, is used to prepare the control samples. For each round three batches of samples are prepared at different lead concentrations. Each batch of samples is prepared using blood from the same donor.

Human blood was chosen in order to ensure that control samples were as similar as possible to patient samples [2]. The preparation of control samples includes several steps. In the first step, blood is haemolysed and little clots are removed. An homogeneous material is produced by sonicating the blood. A measured volume is then transferred to a dispensing vessel with a magnetic stirrer. An aqueous solution of lead nitrate is added to the blood under constant stirring continued for three hours. The amounts of lead added currently range from zero to 750 µg/l; thus the final concentrations in the samples cover the range of values that cause most concern in occupational exposure to lead.

Aliquots (3 ml) are then dispensed into 5 ml plastic vials free from lead contamination. These specimens are then packed for distribution to the participating laboratories.

This procedure has remained unchanged throughout the operation of the scheme (10 years), after initial studies, in the experimental phase, demonstrated the homogeneity of the samples and their stability.

At least five samples of each batch are previously analyzed for homogeneity. The coefficients of variation obtained were always below 4%. Therefore it is assumed that the variations occurring during sample preparation were small in comparison to analytical variation.

Circulation of samples

Every month each participant receives by mail three samples with different concentrations of lead. Results are requested within thirty days, sent by mail, fax or phone. Since at present the scheme is not used for accreditation and participation is voluntary, the names of the participants are known only to those responsible for the organisation of the scheme. Communication is maintained using a reference number for each participant and their analytical method.

Evaluation of results and performance indices

In every EQAS, a critical point is the estimate of the "true value" for each sample. In the PICC-PbS the chosen option is to base it on the mean of the participants'

results (consensus mean) after exclusion of outliers which might unduly bias it.

Therefore we define "accepted results" those which fall within ± 2 SD from the overall mean and the mean of the accepted results is then considered the "consensus mean" for each sample.

To provide additional information, a "target value" is estimated for each sample. This is calculated taking the mean of the results from a group of laboratories who have achieved a good performance in the last three rounds (reference group).

In each round, the laboratories included in the reference group are those who had results within 15% of the "consensus mean" for at least 8 of the last 9 samples. As it could be expected, the variability of the results of the reference group, in each round over the last nine years of activity, is clearly less than the variability for all results and even for the accepted results. The most frequent values for the coefficients of variation are 7-8% for the reference group and 13-14% for the accepted results.

Another problem is to provide a clear and simple index of the performance of individual laboratories. Taking as a model the UK-external quality assessment scheme of the Queen Elizabeth Hospital [3] we use two performance indices:

- the variance index (IV), calculated as the absolute percentage deviation (E) of the result returned by a participant (X) from the consensus mean (D) expressed as a percentage of a chosen coefficient of variation (CCV=15%), i.e.:

$$IV = (E \times 100)/CCV; \quad E = (|X-D| \times 100)/D$$

- the mean variance index (IVM), that is the mean of the last 10 IVs. The IVM is updated every time a result is returned.

In practice an IV = 100 represents a deviation of 15% from the consensus mean. At the same time, if the performance of a laboratory is improving, then the current IV will normally be less than the current IVM. Therefore the lower the IVM of the results of a laboratory the better its performance.

The calculation of performance indices naturally leads to the categorisation of the laboratories. In the PICC-PbS the laboratories who have IV and IVM over 100 show poor performance. Those laboratories who maintain their IVM between 60 and 100 can be considered as having an acceptable performance and those with IVM lower than 60 have a high level of performance.

Reports for the participants

Each participating laboratory is subsequently provided with a report which includes its performance indices and for each sample:

- the results submitted by the laboratories (in anonymous form);
- the histogram of the results;
- the overall mean and the coefficient of variation of all results;
- the mean and the coefficient of variation of the accepted results categorised by analytical method;
- the "consensus mean" and the coefficient of variation of accepted results;
- the "target value", the number and the coefficient of variation of the results used to calculate this value.

Results of the scheme

At present, the PICC-PbS is designed to provide the laboratories with an opportunity to locate systematic errors and to evaluate the results obtained with their analytical procedures. Only laboratories who do not return results regularly are excluded. In general, in each round, 77% of the laboratories return their results.

Since the scheme started, we have seen some improvement in the overall performance of many laboratories. At the end of 1986 the median of all the IVMs was 80, whilst at the end of 1993 it was 59. This shows that a greater number of laboratories are now able to approach the consensus mean in a single round.

Also there has been an increase in the percentage of laboratories capable to continuously maintain a good performance over one year. Thus during 1993, 41% of

the laboratories maintained their IVM below 100 as opposed to 34% in 1985. There has been an even greater improvement in the percentage of laboratories who have a high level of performance: laboratories who maintained their IVM below 60 throughout one year increased from 12 to 18% and those who maintained at least 90% of their results within 15% of the consensus mean increased from 7% to 22%.

Nevertheless there are still many laboratories who do not reach the standard required even though they are concerned with improving their results. This unfortunately leads us to think that the problem of achieving an acceptable performance could be more serious for laboratories who do not participate in any scheme.

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Appendix. - Summary of the scheme

Country	Spain.
Name of scheme	Programa interlaboratorios de control de calidad de plomo en sangre (PICC-PbS).
Status of scheme	International, voluntary. <i>Run by:</i> Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT) <i>Aims:</i> to provide laboratories with the means to: plan their quality assurance; detect trends; assess the performance of their analytical procedures. <i>Participants:</i> 79 participating laboratories, of whom 53% Spanish, 4% Portuguese and 43% from Latin-American countries (1994). The field of activity of 58% of participants is occupational health. The remaining 42% includes hospital laboratories, universities and other work activities related with health, toxicology and environmental protection.
Scheme description	<i>Control materials:</i> in-lab preparation. Human blood matrix. Each batch of samples is prepared from blood from the same donor, free from infectious-contagious factors, to which lead as an inorganic salt is added. Liquid, mono-elemental samples, in plastic vials. "Consensus Mean": calculated for each sample from the results falling within ± 2 SD from the overall mean ("accepted results"). To provide additional information, a "target value" is estimated for each sample. This is calculated taking the mean of the results from a group of laboratories that have achieved a good performance in the last three rounds (at least 8 of the last 9 samples have had results within 15% of the "consensus mean"). <i>Organization of EQA exercises:</i> every month, each participant receives 3 samples, the lead content of which ranges from 20 to 90 $\mu\text{g}/\text{dl}$ (0.965 to 4.343 $\mu\text{mol}/\text{l}$) Distribution: by mail. Time schedule for returning results: 30 days. Methods of transmission of results: communication by mail or by fax is maintained using a reference number (names of the participants are kept anonymous by the organiser) for each participant and their analytical method. <i>Elaboration of results:</i> each participant receives his results and overall picture of all results, histogram, along with the "consensus mean", the "target value" and their performance indices. <i>Criteria for evaluation of laboratory performance:</i> two performance indices are used. The variance index (IV) is calculated as the absolute percentage deviation (E) of the result returned by a participant (X) from the consensus mean (D) expressed as a percentage of a chosen coefficient of variation (CCV=15%), i.e.: $IV = (E \times 100)/CCV$; $E = ((X-D) \times 100)/D$. The mean variance index (IVM) is calculated as the mean of the last 10 IVs. The IVM is updated every time a result is returned. Laboratories are considered to show: poor performance, if IV and $IVM < 100$; acceptable performance, if $60 \leq IVM \leq 100$; a high level of performance, if $IVM < 60$. <i>Measures taken against poor performance:</i> none. <i>Provision of advice and training:</i> none. <i>Financial support:</i> INSHT resources. Participation is free of charge.
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Analytes and matrix covered	Blood lead.