ELSEVIER

Spectrochimica Acta Part B 62 (2007) 992–1003

SPECTROCHIMICA ACTA PART B

www.elsevier.com/locate/sab

Viewpoint

Atomic spectrometry and trends in clinical laboratory medicine☆

Patrick J. Parsons [a,b,*], Fernando Barbosa Jr. [c]

[a] *Wadsworth Center, New York State Department of Health, PO Box 509, Albany, NY 12201-0509, USA*
[b] *Department of Environmental Health Sciences, School of Public Health, The University at Albany, Albany, NY 12201, USA*
[c] *Departamento de Análises Clínicas, Toxicológicas e Bromatológicas, Faculdade de Ciências Farmacêuticas de Ribeirão Preto-USP, Av do Café, s/n, Ribeirão Preto SP, 14040-903, Brazil*

Received 2 March 2007; accepted 5 March 2007
Available online 16 March 2007

Abstract

Increasing numbers of clinical laboratories are transitioning away from flame and electrothermal AAS methods to those based on ICP-MS. Still, for many laboratories, the choice of instrumentation is based upon (a) the element(s) to be determined, (b) the matrix/matrices to be analyzed, and (c) the expected concentration(s) of the analytes in the matrix. Most clinical laboratories specialize in measuring Se, Zn, Cu, and Al in serum, and/or Pb, Cd, Hg, As, and Cr in blood and/or urine, while other trace elements (e.g., Pt, Au etc.) are measured for therapeutic purposes. Quantitative measurement of elemental species is becoming more widely accepted for nutritional and/or toxicological screening purposes, and ICP-MS interfaced with separation techniques, such as liquid chromatography or capillary electrophoresis, offers the advantage of on-line species determination coupled with very low detection limits. Polyatomic interferences for some key elements such as Se, As, and Cr require instrumentation equipped with dynamic reaction cell or collision cell technologies, or might even necessitate the use of sector field ICP-MS, to assure accurate results. Nonetheless, whatever analytical method is selected for the task, careful consideration must be given both to specimen collection procedures and to the control of pre-analytical variables. Finally, all methods benefit from access to reliable certified reference materials (CRMs). While a variety of reference materials (RMs) are available for trace element measurements in clinical matrices, not all can be classified as CRMs. The major metrological organizations (e.g., NIST, IRMM, NIES) provide a limited number of clinical CRMs, however, secondary reference materials are readily available from commercial organizations and organizers of external quality assessment schemes.

Keywords: Atomic spectrometry; Clinical laboratory medicine; AAS; ICP-MS; Speciation

Contents

☆ This paper was presented at the 9th Rio Symposium on Atomic Spectrometry, held in Barquisimeto, Venezuela, 5–10 November 2006, and is published in the special issue of Spectrochimica Acta Part B, dedicated to that conference.

* Corresponding author. Wadsworth Center, New York State Department of Health, PO Box 509, Albany, NY 12201-0509, USA. Tel.: +1 518 474 5475; fax: +1 518 473 7586.
E-mail address: patrick.parsons@wadsworth.org (P.J. Parsons).

0584-8547/$ - see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.sab.2007.03.007

1. Introduction

Until very recently, atomic absorption spectrometry (AAS) was the technique of choice in most clinical laboratories that specialize in elemental analysis. Today, many clinical laboratories are transitioning away from flame (FAAS) and electrothermal (ETAAS) methods for determination of elements of clinical interest, and toward methods based on inductively coupled plasma-mass spectrometry (ICP-MS). But is a complete transition to ICP-MS really inevitable? Is there still a future for ETAAS methods in the clinical domain? Does anyone still use FAAS? According to Taylor et al. [1]: "If ICP-MS has a future in the multielement determination of trace elements in serum, urine and whole blood for a routine laboratory, the method has to be simple." We certainly agree.

In the clinical domain, determination of elemental species, i.e., "speciation," is becoming increasingly valued for nutritional and/or toxicological purposes. In this context it is important that we distinguish between methods that are intended for speciation analysis from methods that are more correctly described as fractionation [2]. Over the past decade, atomic mass spectrometry has revolutionized the field of elemental speciation. Today, ICP-MS is the detector of choice in over half of all studies conducted specifically for speciation [3]. At the 9th Rio Symposium Conference on Atomic Spectrometry, Feldmann [4] posed the question: "Will ICP-MS lose its appeal as the favorite detector for metal speciation, or will we love it all over again?" The current evidence suggests that, at least among clinical practitioners, its potential has yet to be fully realized.

However, which elemental species or metabolites are really important from a clinical perspective? Thus, identification of the structure of the specific compound(s) in our sample becomes desirable. For speciation studies, a molecular mass spectrometric technique, such as electrospray ionization time-of-flight mass spectrometry (ESI-TOF-MS) or matrix-assisted laser desorption/ionization mass spectrometry MALDI-MS, can be used to complement separation methods coupled to ICP-MS.

Do speciation methods address possible artifact formation during sample preparation? Even as the number of papers on speciation analysis increases, enormous challenges persist for the implementation in routine clinical laboratories. There are just a few certified reference materials (CRMs) available that have certified concentrations of specific elemental species, and thus robust method validations are difficult to accomplish. However, the availability of clinical CRMs specifically for speciation methods is expected to improve.

This mini-review focuses on the applications of atomic spectrometry in clinical laboratory medicine. It is intended for the spectroscopist who is new to clinical applications, and who is interested in the current state-of-the art. Clinical scientists, who are not spectroscopists may also find this mini-review useful. For ongoing reviews of the literature, the reader is referred to the annual Atomic Spectrometry Updates (ASU) that specifically address clinical and biological applications, as well as other sources of information [1,3,5–9].

2. Biomonitoring for essential and toxic elements

Essential elements are those that are required by an organism to its maintain normal physiological function. Without the essential elements, the organism cannot complete its normal life cycle or achieve normal healthy growth; many such elements are key components of metalloenzymes or are involved in crucial biological functions, such as oxygen transport, free radical scavenging, or hormonal activity. For human health purposes, the essential elements can be sub-classified according to the concentration (trace or major) in which they are found in body fluids and tissues. A convenient classification of those elements (both essential and nonessential) that are particularly significant from a human health perspective, and of particular interest to analytical chemists, is shown in a summarized periodic table in Fig. 1. Those essential elements that are found at concentrations above 10 mg/L in fluids or above 100 μg/g in tissues are considered the major elements, and they include the group 1 and 2 "electrolyte" elements Na, K, Ca, and Mg. For clinical purposes, trace elements have been defined as those occurring at concentrations of 10 μg/L to 10^4 μg/L in body fluids or 0.01 to 100 μg/g in tissues [10]. Some groups have further sub-classified a group of essential elements at concentrations below 10 μg/L (<0.01 μg/g in tissues) as ultra trace elements [10].

Many nonessential elements are so ubiquitous in the environment that they are easily detected in human body tissues and fluids. Some are relatively benign, but others, such as Pb, Cd, Hg and As, are quite toxic even at concentrations considered trace. The most common, nonessential toxic elements that are encountered in clinical laboratory medicine are denoted in Fig. 1 by red shading. However, it should be noted that all elements, including those considered essential, can exert toxic effects if they are present above a critical concentration threshold [11]. Conversely, when an essential element is present at a concentration below that required for normal healthy growth, such deficiency is also associated with adverse health effects [11–13]. Thus, the toxicity of any element will depend on its concentration, duration, and route of exposure, as well as the chemical form, i.e., chemical species, of the element that is present.

Monitoring the nutritional status of essential elements and assessing exposure of individuals to toxic elements are critical functions of modern clinical laboratories. Today, the assessment of human exposure to background levels of trace elements in the