CHAPTER 5

Contrasts and Comparisons of Instrumentation

5.1 Introduction

A number of techniques and instruments for the measurement of metal concentrations in a variety of matrixes were presented in this Etextbook. The purpose of this chapter is to condense some of the more important information into a few tables for comparison.

5.2 Figures of Merit

There are a number of ways to determine if a technique is *best suited* for a particular situation. These include the detection limit that is required, the chemical and labor cost associated with the analysis, the cost of the instrument required to perform the analysis, and secondary advantages that may or may not be important. These are summarized and discussed below.

5.2.1 Detection Limits

One of the first decisions an analyst must make when determining the appropriate technique or instrument is the required detection limits. Table 5.1 gives a comparison for selected metals for a variety of techniques and instruments. In general, the detection limits decrease from FAAS to ICP-MS (left to right) in the table; better detection limits also cost more money. Detection limits generally range from ppm to ppb levels. And as noted in the relevant chapters, as an instrument achieves better detection limits increasingly purer dilution water and digestion acids are required.

Table 5.1. A Comparison of Detection Limits for a Variety of Techniques and Instruments (in μg/L or ppb). Source: Guide to Inorganic Analysis, Perkin Elmer.

Element	**FAAS**	**Hg/Hydride**	**Graphite Furnace**	**ICP-AES**	**ICP-MS**
As	150	0.03	0.05	2	0.0006
Ca	1.5	NA	0.01	0.05	0.0002
Cd	0.8	NA	0.002	0.1	0.00009
Cr	3	NA	0.004	0.2	0.0002
Cu	1.5	NA	0.014	0.4	0.0002
Fe	5	NA	0.06	0.1	0.0003
Hg	300	0.009	0.6	1	0.016
K	3	NA	0.005	1	0.0002
Mg	0.15	NA	0.004	0.04	0.0003
Mn	1.5	NA	0.005	0.1	0.00007
Na	0.3	NA	0.005	0.5	0.0003
Ni	6	NA	0.07	0.5	0.0004
P	75000	NA	130	4	0.1
Pb	15	NA	0.05	1	0.00004
Sb	45	0.15	0.05	2	0.0009
Se	100	0.03	0.05	4	0.0007
Sn	150	NA	0.1	2	0.0005
Sr	3	NA	0.025	0.05	0.00002
U	15000	NA	NA	10	0.0001
Zn	1.5	NA	0.02	0.2	0.0003

5.2.2 Cost of Analysis

Table 5.2 provides a summary of the price range an analysis would cost when performed at an industrial laboratory per metal and per sample. *The key to*

reducing analysis cost for every technique is to automate the technique by using automatic samplers and data collection and to analyze as many samples as possible with one set of standards and quality assurance/quality control (QA/QC) samples. QA/QC requirements vary from discipline to discipline but it is common to recalibrate after every 20 samples. The information in Table 5.2 indicate that flame-based techniques that can only analyze one element at a time (FAAS and FAES) and labor intensive techniques that are more difficult to automate (cold vapor and hydride generation) have fallen out of favor due to increasing labor costs. These techniques are still commonly used in situations where only a few elements need to be analyzed infrequently. Otherwise it rapidly becomes more economical to purchase a more automated system that will provide better detection limits and one that will analyze multiple elements are the same time.

Table 5.2 The Cost of Analysis of an Element for each Technique/Instrument for Drinking and Waste Water Samples. Prices as based on the analysis of a batch of samples (not an individual sample) and include the costs of calibration of the instrument and all QA/QC samples. Source: Confidential data from a Commercial Consulting Environmental Laboratory (2009 cost estimates)

Technique/Instrument	**Price per Element per Sample (as of 2008)**	**Comment(s)**
Cost of Digestion for Non-Drinking Water Samples	$10 per digestion; an additional charge may be required for complex matrixes	Required when solid matter is present in the water or for sediment and tissue samples.
FAAS/FAES	$10	No longer commonly used in commercial service labs since only one element can be analyzed for at a time.
Hg Cold Vapor/Hydride	$20 - $30	Not commonly used by

		most labs due to labor intensive operations; being replaced by ICP-MS.
Graphite Furnace	$20 - $30	Not commonly used by most labs due to labor intensive operations; being replaced by ICP-MS.
ICP-AES	$10	Most labs offer a price reduction for specific sets of metal analyses.
ICP-MS	$10	Most labs offer a price reduction for specific sets of metal analyses.

5.2.3 Costs of Instruments

The cost of the instrument is a major factor determining if analyses will be completed “in house” or if samples will be sent to a consulting or contract laboratory. Table 5.3 shows the costs of common instruments and those discussed in the Etextbook as of 2008. Three major manufacturers (Agilent, Perkin Elmer, and Thermo Scientific) were consulted and prices were averaged.

Table 5.3. Cost of Instruments used in Measuring Metal Concentrations.

Instrument	**Approximate Price (as of 2008)**
FAAS/FAES with Automatic Sampler	$25 000 - $35 000
FAAS with Graphite Furnace with Automatic Sampler	$50 000
Flame Fluorescence for Hg	$25 000
ICP-AES with Automatic Sampler	$70 000 - $100 000

ICP-MS (with Collision/Reaction Cell, Automatic Sampler and Quadrupole Mass Analyzer)	$150 000 - $180 000

5.2.4 A Summary of Advantages and Disadvantages

Several factors can go into the decision process for determining which instrument to use in an analysis. A summary of these is shown in Table 5.4.

Table 5.4. Advantages and Disadvantages of Each Instrument. Source: Guide to Inorganic Analysis, Perkin Elmer.

Criterion	**FAAS/FAES**	**Graphite Furnace**	**ICP-AES**	**ICP-MS (Quadrupole & CRC)**
Detection Limits	high ppb	sub ppb	sub ppb-ppm	sub ppt
Capability	single element	single element	multi-element	multi-element & isotope
Precision	1-2 %	0.5–5 %	0.1-2 %	0.5-2 %
Interferences: Spectral Chemical Physical	 few many some	 very few many very few	 some very few some	 few some some
Number of Elements that can be Analyzed	>60	>50	>70	>80
Sample Volume Requirements	4-8 mL/min	0.2-1 mL	1-2 mL/min	0.02-2 mL/min
Ease of Use	very easy	More difficult	easy	more difficult

Capable of Independent Operation	no	Yes	yes	yes
Instrument Costs	low	medium	high	very high
Operating Costs	low	High	medium	very high

5.3 Questions

What are ”figures of merit” with respect to analytical measurements?

Contrast detection limits for FAAS, graphite furnace, ICP-AES, and ICP-MS.

Give approximate instrument costs for the techniques discussed in this book.

Give approximate detection limits for each instrument/technique discussed in this book.