

Abstract

Social Responsibility (SR) in Analytical Chemistry, the central topic of this chapter, constitutes the synergistic combination of the concepts contained of the previous two chapters of Part III: “Analytical problem-solving” and “Analytical Quality”. The part is concerned with the socio-economic projection of Analytical Chemistry. The initial sections of this chapter provide a brief description of the key notions underlying the Social Responsibility inherent in individuals, organizations, and scientific and technical areas, which is essential for life today. The remainder of the chapter discusses the internal and external connotations of Social Responsibility in the analytical chemical realm. The notions associated to these two facets are illustrated with a number of real-life examples.

Teaching Objectives

- To introduce students to the concept of “Social Responsibility”.
- To highlight the crucial role of SR in Science and Technology.
- To describe SR in Analytical Chemistry and define SR in (bio)chemical information.
- To apply the traceability concept to various facets of Analytical Chemistry and their integration.
- To distinguish the internal and external connotations of SR in Analytical Chemistry using a variety of real-life examples.

Electronic supplementary material The online version of this chapter (doi:[10.1007/978-3-319-62872-1_9](https://doi.org/10.1007/978-3-319-62872-1_9)) contains supplementary material, which is available to authorized users.

9.1 Explanation of the Slides

Slide 9.1

The image shows a table of contents for 'FOUNDATIONS OF ANALYTICAL CHEMISTRY'. The title is in a dark blue bar at the top. Below it, 'PART III SOCIO-ECONOMIC PROJECTION OF ANALYTICAL CHEMISTRY' is highlighted in a yellow box. Underneath, 'Chapter 7. Analytical problem-solving' and 'Chapter 8. Analytical Chemistry and Quality' are listed. 'Chapter 9. Social responsibility in Analytical Chemistry' is highlighted in a green box with a red arrow pointing to it from the left. Below this, 'PART I. INTRODUCTION TO ANALYTICAL CHEMISTRY', 'PART II. THE ANALYTICAL PROCESS', 'ANNEX 1. GLOSSARY OF TERMS', and 'ANNEX 2. ANSWERS TO THE QUESTIONS' are listed in separate colored bars.

FOUNDATIONS OF ANALYTICAL CHEMISTRY
PART III SOCIO-ECONOMIC PROJECTION OF ANALYTICAL CHEMISTRY
Chapter 7. Analytical problem-solving
Chapter 8. Analytical Chemistry and Quality
Chapter 9. Social responsibility in Analytical Chemistry
PART I. INTRODUCTION TO ANALYTICAL CHEMISTRY
PART II. THE ANALYTICAL PROCESS
ANNEX 1. GLOSSARY OF TERMS
ANNEX 2. ANSWERS TO THE QUESTIONS

This slide places Social Responsibility (SR) in Analytical Chemistry in the context of Part III (“Socio-economic Projection of Analytical Chemistry”) and depicts the other two parts, which, as shown in Slide 7.4, are mutually related. This is the third, last chapter in the part and completes the description of the relationships of Analytical Chemistry to society, industry and the economy, for which information continues to be a key element.

Slide 9.2

PART III
SOCIO-ECONOMIC PROJECTION OF ANALYTICAL CHEMISTRY

**Chapter 9: Social responsibility
in Analytical Chemistry**

Contents

- 9.1.1. Introduction
- 9.1.2. The concept of “Social responsibility”
- 9.1.3. Social responsibility in Science and Technology
- 9.1.4. Social responsibility in (bio)chemical information
 - 9.1.4.1. Definition
 - 9.1.4.2. Internal connotations
 - 9.1.4.3. External connotations

Teaching objectives

- To introduce students to the concept of Social Responsibility (SR).
- To highlight the role of SR in Science and Technology.
- To describe SR in Analytical Chemistry and, especially, in its main output: (bio)chemical information.
- To distinguish the internal and external connotations of SR in Analytical Chemistry.

9.2.1. The contents of this chapter are organized in four sections including an Introduction and three others describing the general meaning of SR and its particular meaning in connection to Science and Technology. The chapter then focuses on SR in Analytical Chemistry, which is defined in equivalent terms, and on its internal and external connotations.

9.2.2. The slide also shows the teaching objectives of the chapter as regards SR in general and SR in Analytical Chemistry in particular.

9.1.1 Introduction (2 Slides)

Slide 9.3

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.1. Introduction (I)

- **Social responsibility (SR)** is a relatively new concept associated not only to organizations (e.g., companies), but also to individuals and areas of human activity.
- **Social responsibility in Analytical Chemistry** is that inherent in its main goal: to produce quality (bio)chemical information.
- **Social responsibility in Analytical Chemistry** is approached here in a contemporary manner across the three chapters of Part III.

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graph TD; C7[Chapter 7  
ANALYTICAL  
PROBLEM-  
SOLVING]; C8[Chapter 8  
ANALYTICAL  
CHEMISTRY  
AND QUALITY]; C9[Chapter 9  
SOCIAL RESPONSIBILITY  
IN ANALYTICAL CHEMISTRY]; C7 --- C8; C7 --- C9; C8 --- C9;
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9.3.1. This slide introduces the contents of the chapter, which is essentially concerned with Social Responsibility and its adaptation to Analytical Chemistry.

The SR concept arose with great strength as a complement to “quality”—a vogue word in the last quarter of the XX century—early in the next. The concept is transversal in nature and is currently applied not only to organizations and businesses, but also to industrial, scientific and technical areas, for example.

9.3.2. This chapter deals with SR in a modern manner that connects to, and integrates, the other chapters dealing with the socio-economic projection of Analytical Chemistry.

Slide 9.4

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.1. Introduction (II)

Social responsibility in (bio)chemical information is associated to SR in Analysis (Analytical Chemistry)

- This is a **basic facet** inherent in an honest, ethical conduct of the party producing (bio)analytical information and that receiving it.
- And also a **(relatively) new concept** in Analytical Chemistry that can benefit from previous successful developments in Corporate Social Responsibility.
- Providing an integral definition of SR in Analysis requires considering both **internal and external connotations**.

9.4.1. Social Responsibility in Analytical Chemistry is fully consistent with SR (bio)chemical information. In fact, the (bio)chemical information required by clients and delivered by analytical chemical laboratories should be communicated honestly and ethically between the two parties. Information constitutes a major social power today (see Slides 1.15 and 1.16).

9.4.2. Social Responsibility is a fairly new concept which, however, has always underlain Analytical Chemistry. Some of the great developments in Corporate SR from the 50s can be easily extrapolated or adapted to scientific and technical areas such as Analytical Chemistry.

9.4.3. The nature and impact of SR in Analytical Chemistry are best understood by considering its internal and external connotations as done in this chapter.

9.1.2 The Concept of “Social Responsibility (9 Slides)”

Slide 9.5

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.2. The concept of Social Responsibility (I)

DEFINITION (I)

ISO 26000:2010

The responsibility of an organization or human activity for the social and environmental **impact of its actions and decisions** should be assumed through an ethical, transparent conduct that will

- **facilitate sustainable development and social well-being;**
- **consider the expectations of all stakeholders;**
- **comply with applicable laws;**
- **be consistent with international standards of conduct; and**
- **be integrated throughout the organization or activity concerned, and enforced in all of their relations.**

Social Responsibility has been defined in a number of ways in the corporate realm. Each definition emphasizes some specific aspect. Thus, the most frequently underscored notions in forty definitions found in the literature are as follows:

- stakeholders (88% of definitions) (see Slide 9.8),
- social impact (88%),
- economic impact (86%),
- voluntariness (80%), and
- environmental impact and sustainability (59%).

This slide shows one of the “official” definitions: that in the written standard ISO 26000:2010 for SR in human organizations and activities (see Slide 1.14). Interestingly, the definitions in ISO standards contain the defined term (“responsibility”) when an alternative word such as “awareness” would probably be more appropriate.

The terms *impact* (social and environmental), *ethics* and *transparency and compliance with laws and norms* are essential to fulfil SR. Although these notions are described in detail in discussing the SR principles contained in the standard (see Slide 9.12), some relatively unusual terms in it merit clarification in the following slides.

Slide 9.6

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.2. The concept of Social Responsibility (II)

DEFINITION (II)

Most definitions of SR distinguish social impact and environmental impact.

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graph TD
    IMPACT([IMPACT]) --> SOCIAL[SOCIAL]
    IMPACT --> ENVIRONMENTAL[ENVIRONMENTAL]
    SOCIAL --- PRESENT[PRESENT]
    ENVIRONMENTAL --- FUTURE[FUTURE]
  
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This slide illustrates the basic meaning of SR, namely: the impact on society (with provision for the present) and on the environment (looking into the future). However, dissociating the impact on society and the environment is completely unwarranted (as can be seen, the two are clearly overlapped).

Slide 9.7

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.2. The concept of Social Responsibility (III)

Meaning of “RESPONSIBILITY”

Responsibility is a human value in the conscience of individuals or groups that allows them to

manage ● reflect on

● guide

judge ●

↓

the consequences of their actions

Responsible individuals and groups are aware of their being the direct or indirect sources of actions affecting stakeholders. →

Other meanings of “responsible”:

- Those who carefully plan what they do and decide.
- Those who are guilty of something (an action, a crime).
- Those who rule some activity (e.g., in the corporate realm)

This slide summarizes the meaning of “responsibility”, which is an ethical value of individuals or groups allowing them to reflect on, manage, guide and judge the consequences of their actions.

Awareness and acceptance of the direct and indirect consequences of such actions on stakeholders are key elements of responsibility (see Slide 9.8).

The word “responsibility” can have other meanings depending on the particular context. The slide shows some.

Slide 9.8



9.8.1. Stakeholders are individuals or groups receiving outputs (e.g., products, environmental pollution) from some organization (e.g., a company, a scientific or technical area). Also, they can influence the organization in some way (e.g., by compelling it to improve its products, lower its prices and/or reduce pollution).

Therefore, the activities of an individual, an organization, or a scientific or technical area have an impact on stakeholders, and stakeholders can cause such activities to be remodelled. Closing this cycle is a key to practicing Social Responsibility.

9.8.2. There are two main types of corporate stakeholders, namely:

- (a) *classic* (clients, shareholders, investors, employees, financial institutions, sub-contractors); and
- (b) *new* (think-tanks, social communities, partnerships, NGOs).

Slide 9.9

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.2. The concept of Social Responsibility (V)

Definition of “SUSTAINABILITY”

OXFORD ENGLISH DICTIONARY

“**Sustainable**” (adjective):
Of a process: that can continue to develop by itself (e.g., economic development without external support or the loss of existing resources).

“**Sustainability**” (noun):
The quality of being sustainable.

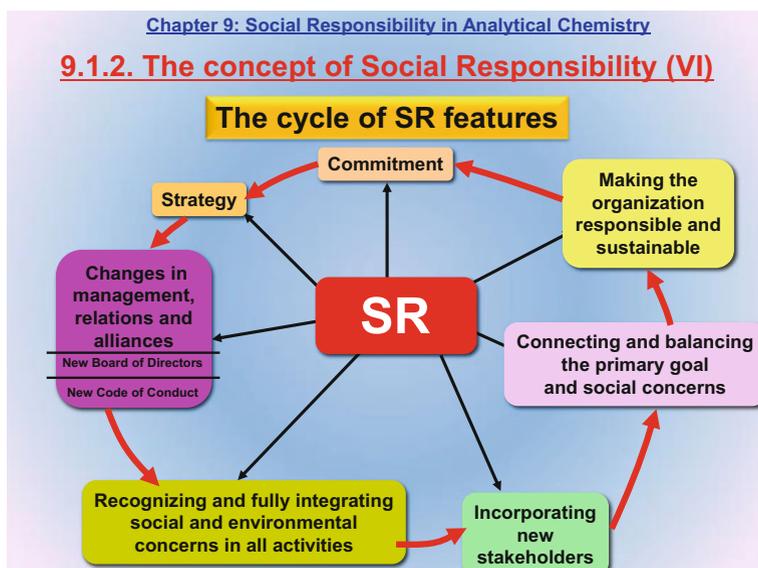
ISO 26000:2010

“**Sustainable development**”:
That meeting present needs without compromising the ability of future generations to meet theirs.

The environmental impact of SR is closely related to “sustainability”, the concept illustrated in this slide.

Broadly speaking, a process is deemed sustainable if it can continue to develop by itself.

ISO standards on SR establish a direct link between sustainability and the environment.



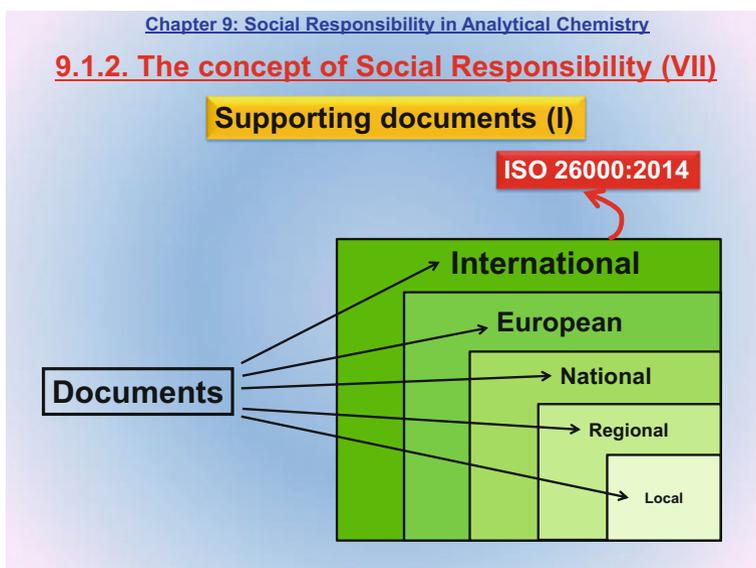
The concept cycle defining SR in an integral manner is a succession of complementary facets.

First, SR entails an explicit, written commitment to adopt a new strategy leading to substantial managerial changes in organizations or activity areas that will materialize in a new code of conduct.

Because the target activities should respond to social and environmental concerns, classic stakeholders usually need to be expanded with new stakeholders.

For an organization or activity area to be responsible and sustainable, Social Responsibility should be the link and balancing factor for its main goals, and its social and environmental concerns. This obviously requires a strong commitment that closes the SR cycle.

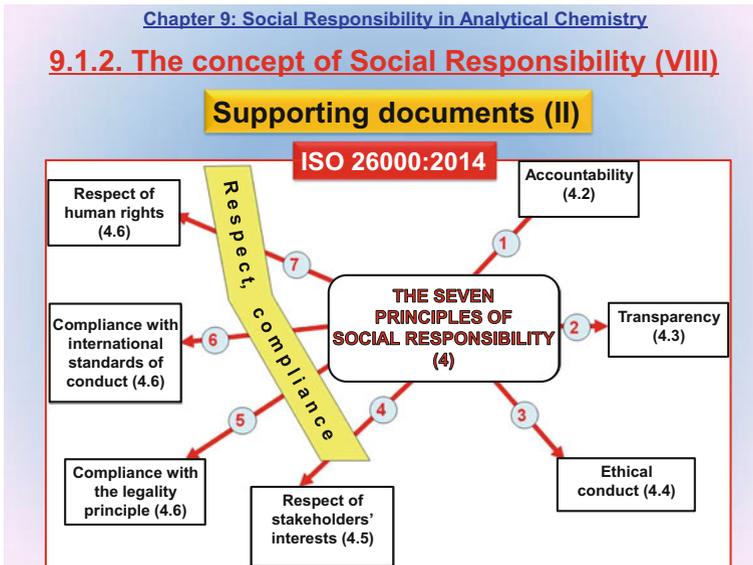
Slide 9.11



Social Responsibility has been the subject of a myriad of documents issued by local or regional councils, countries and international institutions since the turn of the century. As shown in this slide, they feed back in the opposite direction. The most widely accepted and used SR documents include ISO Guide 26000:2014 on the establishment of Social Responsibility in organizations. These documents can be considered a written standard (see Slide 1.15).

Such a vast amount of documents has no doubt facilitated adoption of SR and its practical development.

Slide 9.12



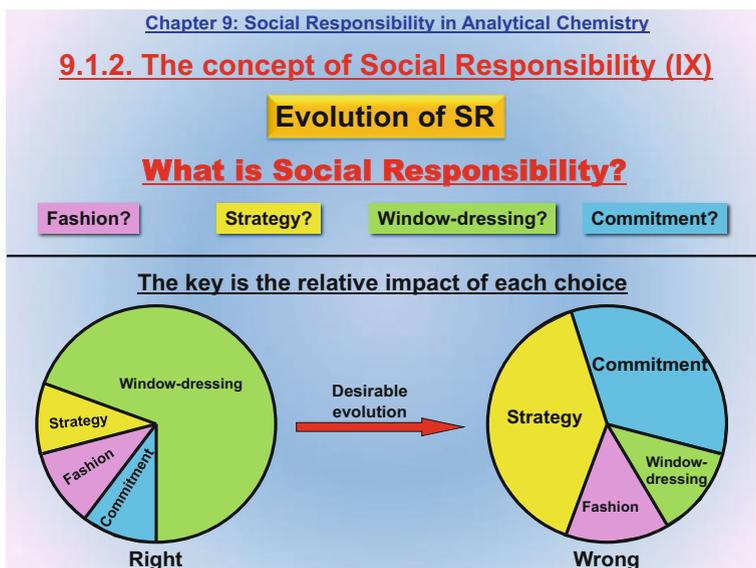
Item 4 in ISO Guide 26000:2010 lists the seven cornerstones or principles underlying Social Responsibility, which are essential in order to understand and assume the concept.

The first three principles are *accountability*, *transparency* and *ethical conduct*. Social Responsibility thus includes ethical conduct despite the reluctance of classic stakeholders to admit it. These principles are essential and go beyond the bounds of quality.

The other four principles can be merged into a single one. In fact, all share the notions respect and compliance with specific values; three such values (human rights, international standards of conduct and law) are general in scope whereas the fourth (stakeholders' interests) is specific.

Especially prominent among the seven principles is *stakeholders' integral satisfaction*, where all others converge.

Slide 9.13



9.13.1. Social Responsibility emerged momentarily early in this century. Since then, advocates and critics have deemed SR a short-lived fashion;

9.13.2. a genuine strategy for improvement;

9.13.3. self-interested window-dressing; and

9.13.4. a commitment to society and the environment.

9.13.5. The current scenario may be distorted in the wrong direction (e.g., window-dressing and a prevalence of self-interest).

9.13.6. This situation should evolve to a prevalence of the genuine facets of SR (strategy and commitment) at the expense of “marketing” (fashion, window-dressing)—which can be a legitimate additional aim provided priority is given to strategy and commitment.

9.1.3 Social Responsibility in Science and Technology (2 Slides)

Slide 9.14

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.3. SR in Science and Technology (I)

Specific notions (I)

Science and Technology
“Scientific Social Responsibility: A call to arms”.
P. Krogsgaard-Larsen, P. Thostrup, F. Besenbacher
Angew. Chem. Int. Ed., 2011, 50, 2–4

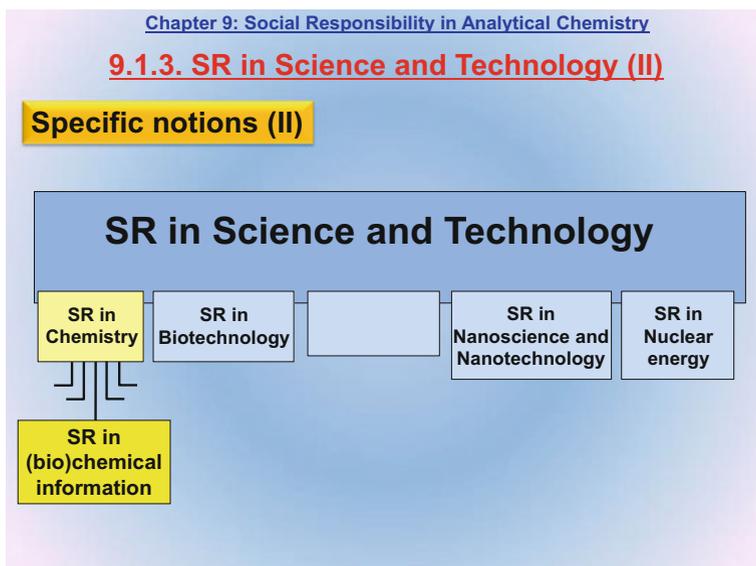
Chemistry
“The Social Responsibility of chemists: Responsible
stewardship”. International Union of Pure and
Applied Chemistry (IUPAC)
IUPAC Project 2006-043-3-050. Research Triangle
Park, NC, USA. 2006.

**Analytical
Chemistry**
“Social Responsibility in Analytical Chemistry”
M. Valcárcel, R. Lucena
Trends Anal. Chem., 2012, 31, 1–7

Like any human activity, scientific and technological progress through research, development and transfer (R&D&T) should not evade its Social Responsibility.

This slide shows several pieces of scientific literature showing that each step in the Science and Technology–Chemistry–Analytical Chemistry hierarchy is amenable to application of the SR concept.

Slide 9.15



The notions of slide in 9.14 are depicted schematically here. As can be seen,

9.15.1. Social Responsibility in Science and Technology...

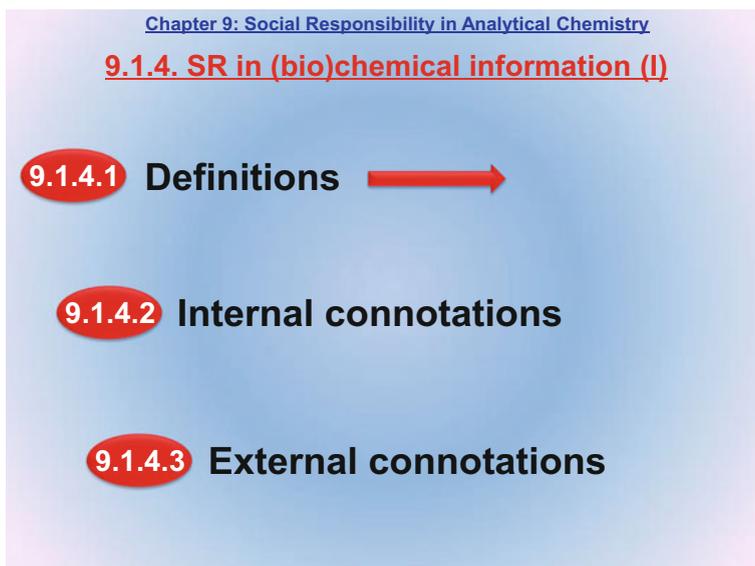
9.15.2. ...comprises SR in Chemistry, Biology, Biotechnology, Nanotechnology, and many other scientific and technical areas.

9.15.3. In turn, Social Responsibility in Chemistry encompasses its various disciplines including Analytical Chemistry, where SR reaches (bio)chemical information.

9.1.4 Social Responsibility in (Bio)Chemical Information (36 Slides)

9.1.4.1 Definition and Contextualization (8 Slides)

Slide 9.16



The fourth, last section of this chapter describes Social Responsibility in (bio)chemical information, which is the main output of Analytical Chemistry. Consequently, SR in (bio)chemical information is equivalent to SR in Analytical Chemistry.

The definition of (bio)chemical information and its Social Responsibility in Sect. 9.1.4 is followed by a description of its internal and external connotations (Sects. 9.1.4.1 and 9.1.4.2, respectively), which are indispensable with a view to approaching SR in Analytical Chemistry in an integral manner.

Slide 9.17

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (II)

9.1.4.1. Definition of “(bio)chemical information” (I)

- “The product of a (bio)chemical measurement process” (that is, of Analysis, which is a basic element of Chemistry in addition to Theory, Synthesis and Applications).
- (Bio)chemical information provides a **chemical and/or biochemical description of natural or artificial objects** intended to facilitate
 - a better understanding of processes and mechanisms with a view to supporting interdisciplinary R&D&I; and
 - well-founded, efficient decision-making in the social, technical, economic and scientific realms.

9.17.1. The concept of (bio)chemical information is explained broadly in Chap. 1. This is the third basic component of Chemistry and the “output” of (bio)chemical measurement processes (that is, of the “Analysis” of objects and systems).

9.17.2. (Bio)chemical information constitutes the chemical or biochemical description of natural or artificial objects or systems for two general purposes, namely:

- acquiring a better understanding of the processes and mechanisms, whether chemical or otherwise, involved in research, development and transfer activities; or
- making well-grounded, timely decisions in the social, technical, economic or scientific realm.

This definition is enriched with enlightening nuances in the following two slides.

Slide 9.18

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (III)

9.1.4.1. Definition of “(bio)chemical information” (II)

- **EQUIVALENCE OF “(BIO)CHEMICAL INFORMATION” AND “ANALYTICAL INFORMATION”**

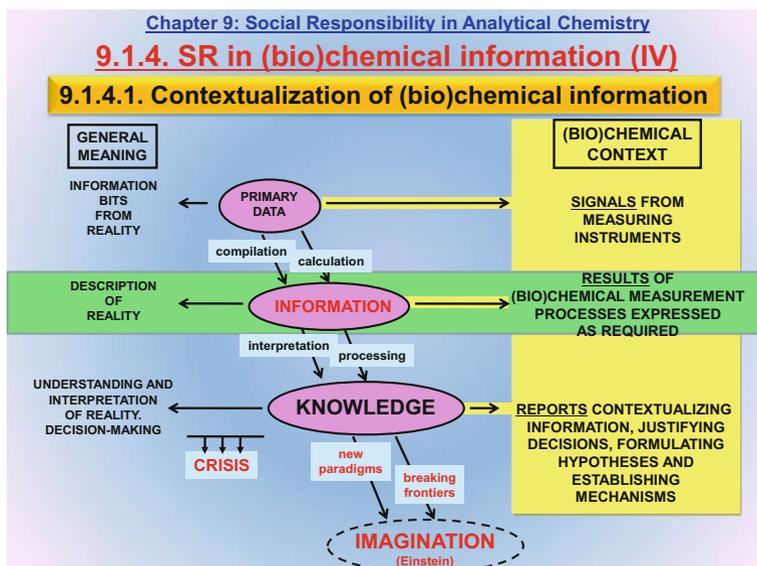
- **A WEAK DISTINCTION BETWEEN “CHEMICAL ANALYSIS” AND “BIOCHEMICAL ANALYSIS”. THE RIGHT CHOICE DEPENDS ON THE NATURE OF THE**

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graph TD; Root[ ] --- S[SAMPLES]; Root --- A[ANALYTES]; Root --- T[TOOLS]; S --- S1[SOIL/KIDNEY TISSUE]; A --- A1[CHLORIDE/PROTEINS]; T --- T1[ORGANIC REAGENTS / IMMOBILIZED ENZYMES];
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“(Bio)chemical information” and “analytical information” are two equivalent terms. In this book, *(bio)chemical information* is used for simplicity to refer to both chemical information (e.g., the concentration of a banned adulterant in a soft drink) and biochemical information (e.g., the total protein content of blood serum).

The difference between “chemical analysis” and “biochemical analysis” is not categorical either. Thus, the designation of choice in each case depends on the nature of the samples (e.g., waste water, spinal marrow), analytes (e.g., iron, an enzyme) and analytical tools (e.g., inorganic reagents, immobilized enzymes).

Slide 9.19



9.19.1. Dealing with “information” in isolation in this hierarchy, which is also shown in Slide 1.20, makes no sense. In fact, information (a description of reality) is obtained by compiling raw (primary) data (that is, information components of reality).

Processing and interpreting information produces “knowledge” (an understanding and interpretation of reality that facilitates decision-making).

According to Einstein, in critical times where knowledge does not suffice, humans must create new paradigms and cross boundaries between scientific and technical areas (interdisciplinarity) to reach “imagination” (or its etymological equivalent, “innovation”).

9.19.2. This ranking is easily adapted to the (bio)chemical context. Thus,

- “signals” from measuring instruments are “primary data”;
- “results” of measurement processes, expressed as required by the clients, constitute “information”; and
- “reports”, equivalent to “knowledge”, help to contextualize information, make decisions, formulate hypotheses and elucidate mechanisms.

Analytical Chemistry is not impervious to crises arising from a variety of situations such as new information requirements in unusual settings. One case in point is information from the Nanoworld, extraction of which poses a great challenge that can only be met by leaving traditional physico–chemical concepts behind and approaching problems in a multidisciplinary manner.

Slide 9.20

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (V)

9.1.4.1. Definition of SR in (bio)chemical information (I)

*“The **impact** on society, and on health, the environment, industries, agrifood, etc., of **(bio)chemical knowledge** derived from the analysis of objects and systems, whether natural or artificial.”*

● Note the differences between “information” and “knowledge” in Slide 9.19
● SR in (bio)chemical information coincides with SR in Analytical Chemistry

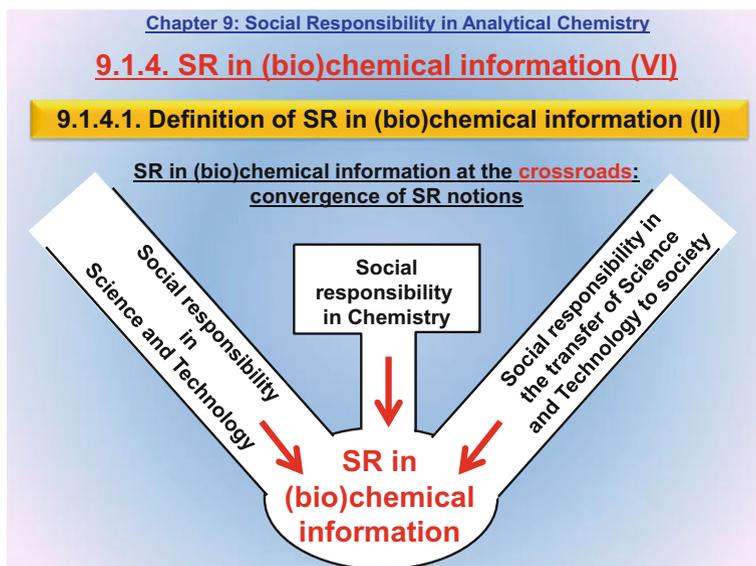
9.20.1. Social Responsibility (SR) in (bio)chemical information, which is equivalent to SR in Analytical Chemistry, is defined here as the social and environmental impact of (bio)chemical knowledge derived from the information (output) provided by analytical processes applied to natural or artificial objects and systems.

One should bear in mind here the differences between “information” (results) and “knowledge” (reports) established in the previous slide.

9.20.2. The Social Responsibility of Analytical Chemistry comprises

- internal connotations (the reliable, sustainable production of knowledge); and
- external connotations (ensuring that delivered knowledge is fully consistent with reality).

Slide 9.21



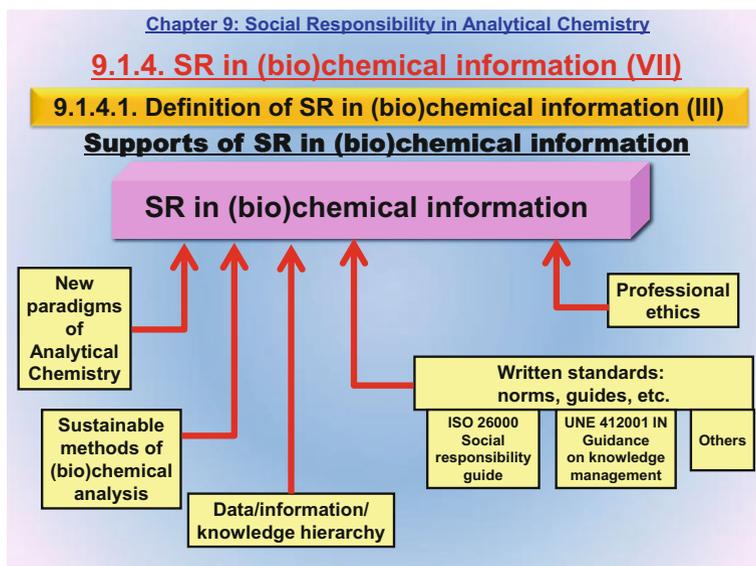
9.21.1. Social Responsibility in (bio)chemical information is at the crossroads of three converging concepts, namely:

9.21.2. SR in Science and Technology;

9.21.3. SR in Chemistry; and

9.21.4. SR in the transfer of scientific and technological outputs to society.

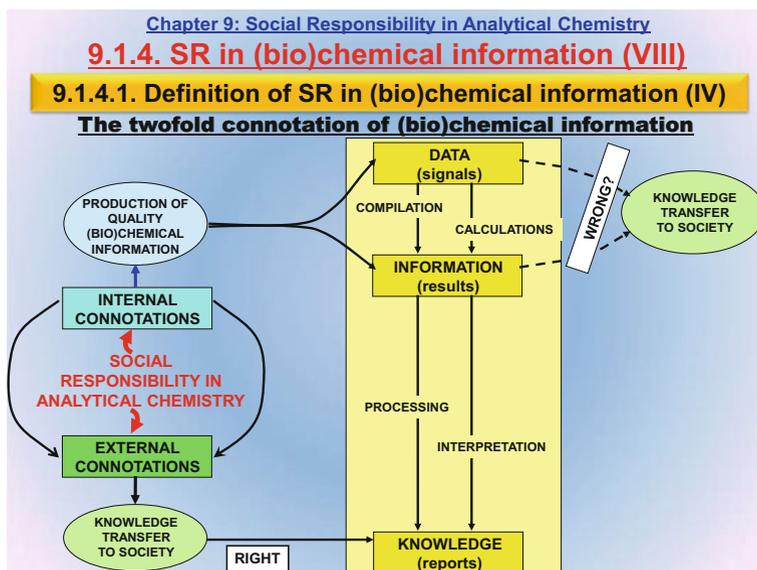
Slide 9.22



Social Responsibility in (bio)chemical information rests on the following five cornerstones:

- a contemporary view of Analytical Chemistry and its new paradigms that has inspired the contents of this book;
- sustainable (green) methods of (bio)chemical analysis (see Slide 9.26);
- the data–information–knowledge–imagination hierarchy explained in Slide 9.19;
- written standards such as the ISO Guide to Social Responsibility and Knowledge Management, among others; and
- professional ethics in the information producer and receiver.

Slide 9.23



9.23.1. This slide illustrates the twofold connotation of Social Responsibility in (bio)chemical information with the data–information–knowledge hierarchy (see Slide 9.19).

9.23.2. Social Responsibility in Analytical Chemistry, and hence SR in (bio)-chemical information, has internal and external connotations.

9.23.3. The internal connotations materialize in the production of data and information, which, as shown below, can be correctly or incorrectly transferred to society.

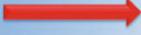
9.23.4. The external connotations revolve around the transfer of knowledge in the form of reports contextualizing and interpreting the information produced by a laboratory to be delivered to society.

Slide 9.24

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (IX)

9.1.4.1 Definitions

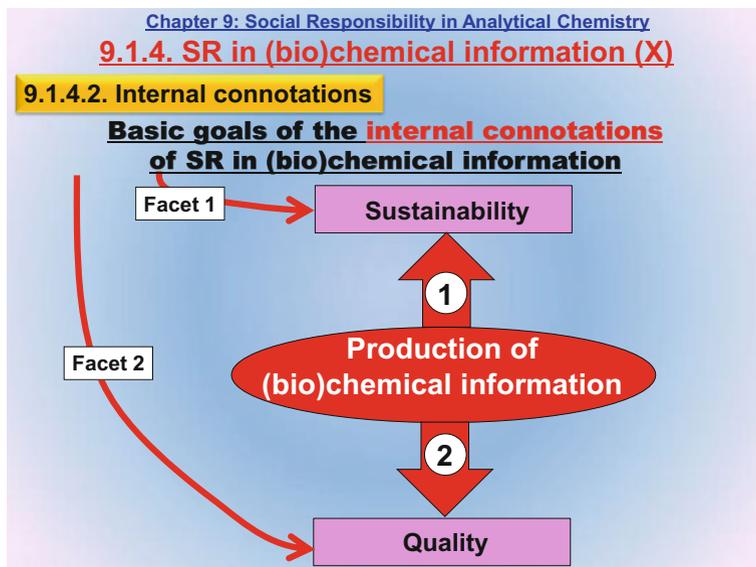
9.1.4.2 Internal connotations 

9.1.4.3 External connotations

The following five slides discuss the internal connotations of Social Responsibility in (bio)chemical information derived by compiling data produced by a laboratory (e.g., instrument measurements) or processing data obtained on-site (e.g., by monitoring water in a river with a remote pH sensor continuously sending readings to the laboratory).

9.1.4.2 Internal Connotations (6 Slides)

Slide 9.25



9.25.1. The internal connotations of Social Responsibility in (bio)chemical information are related to its production and materialize in reaching two different goals.

9.25.2. One goal (Facet 1) is the sustainable production of (bio)chemical information, which entails avoiding personnel hazards and environmental pollution (e.g., from laboratory waste).

9.25.3. The other goal (Facet 2) is to ensure quality in the (bio)chemical information produced, which requires ensuring that it is consistent with the (bio)-chemical reality to be described and fulfilling the client's needs (e.g., expeditious delivery).

Slide 9.26

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XI)

9.1.4.2. Internal connotations: (1) Sustainability

“Green” analytical methods

(1) Goal

To avoid polluting the environment (air, water, soil) by effect of operations performed in the analytical process.

(2) Main strategies

1. Direct methods of analysis (without solvents).
2. Replacing toxic reagents with less toxic or non-toxic reagents.
3. Miniaturizing analytical processes: using reagents produces waste.
4. Automating analytical processes.
5. Developing on-line and off-line decontamination or laboratory waste storage processes.

Sustainability in the production of (bio)chemical information has been sought by developing so-called *green analytical methods*, which have been the result of much analytical chemical research.

Green methods are intended to reduce air, water, soil and animal pollution by effect of analytical processes.

The following are obvious poor laboratory practices:

- Directly releasing organic or inorganic volatiles formed during an analytical process to the atmosphere or simply not avoiding exposure of laboratory staff to their vapours as a result of not complying with occupational risk prevention regulations.
- Disposing of organic or inorganic solvents or reagents such as sulphuric, nitric or hydrochloric acid through laboratory sinks, thus severely contaminating urban waste water. The applicable Good Laboratory Practice in developed countries compels that hazardous waste should be properly stored in the laboratory for periodic collection by waste handling companies.

Green methods can be implemented in various ways with a view to minimizing the negative impact of analytical processes on staff health and the environment the most salient of which are as follows:

- Simplifying the analytical process by using direct analyses involving no intermediate operations in order to considerably reduce or even completely dispense with the use of potentially polluting solvents and reagents.
- Replacing traditional toxic reagents (e.g., mercury-based compounds) with safer alternatives.
- Downscaling (miniaturizing) the analytical process to minimize use of potentially hazardous solvents and reagents.
- Partially or completely automating the analytical process in order to decrease staff risks by reducing human involvement.
- Developing effective laboratory decontamination procedures to be performed on-line (as part of the analytical process) or off.

Slide 9.27

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XII)

9.1.4.2. Internal connotations: (2) Quality (I)

1 Twofold, contradictory facet of Analytical Chemistry

(1) High metrological quality high accuracy, minimal uncertainty)

(2) Satisfying the client's information requirements (solving the analytical problem)

Balance

Quality trade-offs are required to solve the problem: consistency between theory and practice

2 Types of (bio)chemical information according to quality

The second internal facet of SR in (bio)analytical information has to do with analytical quality (Chap. 8).

One should bear in mind the contradictory relationship between the two main goals of Analytical Chemistry (see Chap. 1, Slides 1.8 and 1.9), namely:

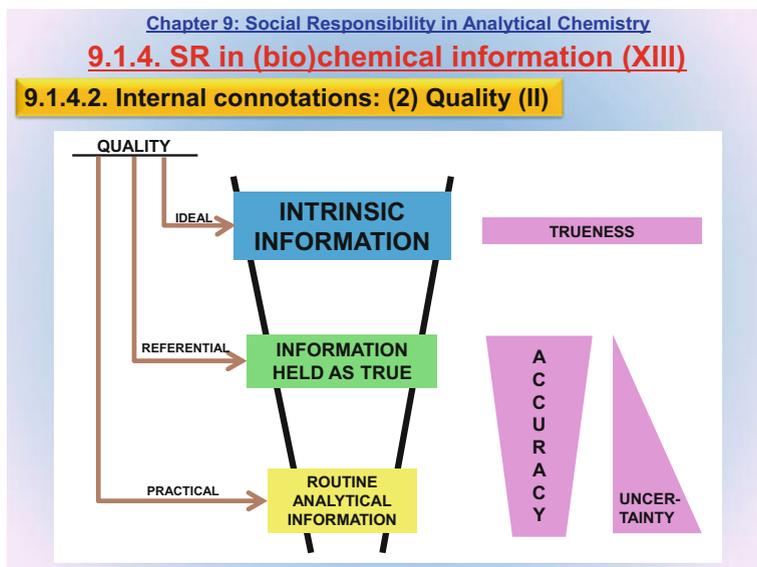
- (1) to maximize the accuracy and minimize the specific uncertainty of results; and
- (2) to fulfil information requirements (that is, to solve analytical problems) (Chap. 7).

Both goals are discussed in Slide 1.9.

In some cases, information requirements must be met within a short time or at a low cost and hence in contradiction with the first goal. As a result, analytical chemists are permanently confronted with the need to adopt “quality trade-offs”.

(Bio)chemical information can be classified in the two ways explained in Slides 9.28 and 9.29.

Slide 9.28

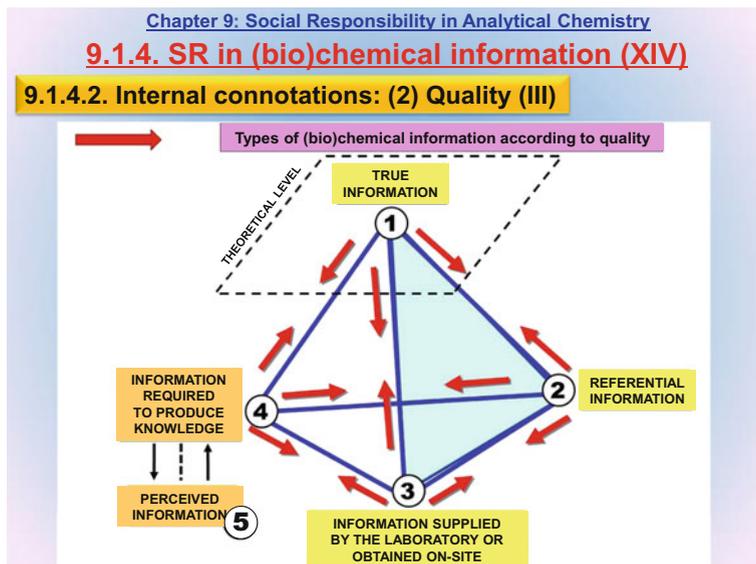


There are three different types of (bio)chemical information according to quality, namely: ideal, referential and practical, which correspond to true (intrinsic) information, information held as true and routine information. This scheme is also present in Slide 1.17.

The ideal notion of trueness corresponds to true or intrinsic information about objects or systems. On the other hand, information held as true is associated to a certified reference material (CRM) and routine information is laboratory-produced information.

In this hierarchy, accuracy decreases with decreasing quality from intrinsic information (absolute accuracy). Conversely, uncertainty increases with decreasing information quality and is lowest in intrinsic information (zero uncertainty).

Slide 9.29



This quality ranking of analytical information supplements that in the previous slide and introduces two additional quality-related concepts. One can therefore define five different quality concepts (1–5), namely:

- (1) True (ideal) information about analysed objects and systems, which is purely theoretical because it is inaccessible to humans.
- (2) Referential information, which is that usable in practice. This is the type of information extracted from CRMs. Unfortunately, referential information is not easy to obtain owing to the high cost of CRMs and their scarcity (only about 5% of current needs in this respect are estimated to be fulfilled).
- (3) Information derived from laboratory (e.g., instrument signals) or on-site acquired data.

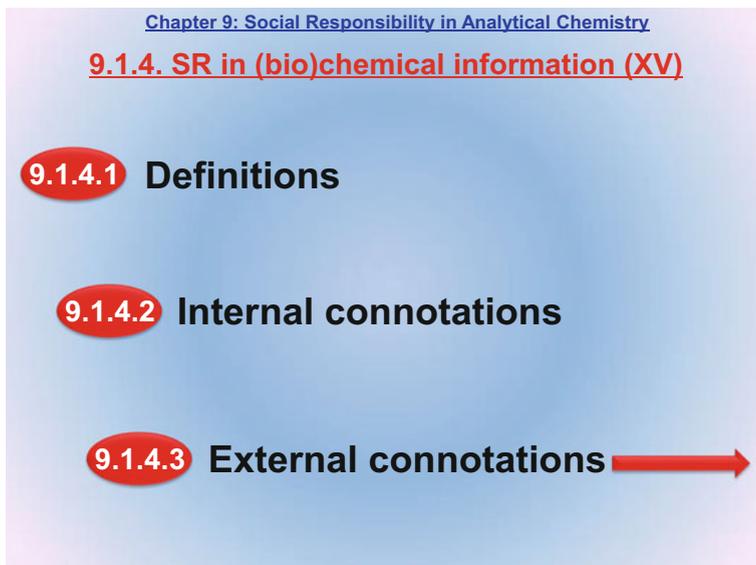
These three notions of quality in (bio)chemical information can be placed at the vertices of the triangle shown in the previous slide.

- (4) The information to be delivered so that clients can obtain the knowledge needed to meet their information requirements is another quality concept. Although it falls outside the scope of the laboratory, analytical chemists remain responsible for cooperating with clients in order to properly understand what they need from the laboratory.
- (5) Finally, the client's perceived quality in the information received is very important but rarely considered. Although the relationship of perceived

information to required information is especially important, it is beyond the scope of this book.

The tetrahedron outlines the contradictory and complementary binary and ternary relationships between the four basic types of (bio)chemical information. A detailed discussion of such relationships is also beyond the scope of this book, however.

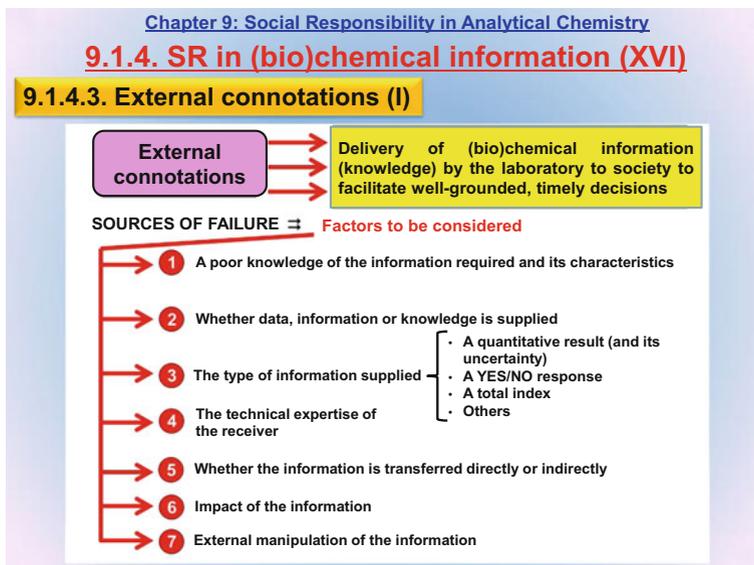
Slide 9.30

The slide has a light blue background with a gradient. At the top, the text 'Chapter 9: Social Responsibility in Analytical Chemistry' is written in a small blue font. Below it, the title '9.1.4. SR in (bio)chemical information (XV)' is written in a larger red font. The main content consists of three items, each with a red oval containing a white number and a black text label: '9.1.4.1 Definitions', '9.1.4.2 Internal connotations', and '9.1.4.3 External connotations'. A red arrow points to the right from the end of the text 'External connotations'.

Slides 9.31 to 9.44 describe the relevant external connotations of Social Responsibility in (bio)chemical information.

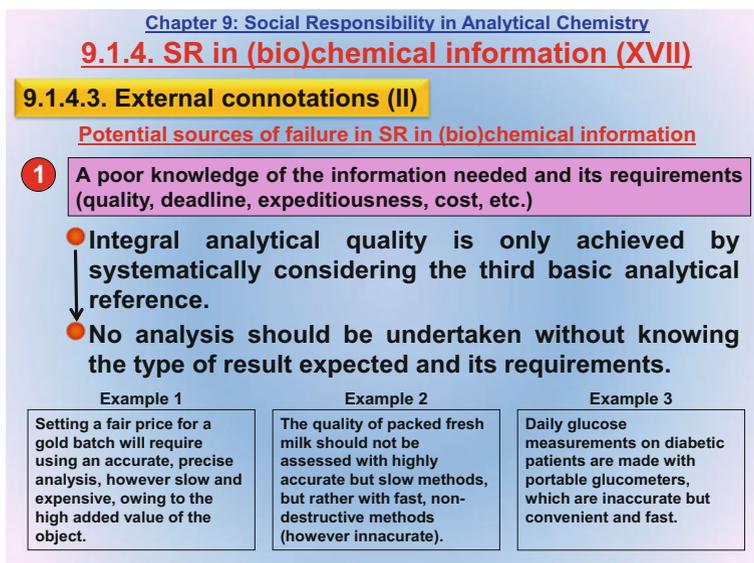
9.1.4.3 External Connotations (15 Slides)

Slide 9.31



The external connotations of SR in (bio)chemical information materialize in its correct transfer to society in order to facilitate well-grounded, timely, cost-effective decisions. Unfortunately, the transfer can fail for a number of reasons. Seven of the most common are depicted in this slide and described in detail in the next few.

Slide 9.32



The most common sources of failure in the transfer of (bio)chemical information from the laboratory to society include the following:

- (1) poor communication with the client;
- (2) an inordinate interest in achieving analytical quality, which is incompatible with laziness or carelessness in either party; and
- (3) adhering to a strict protocol which does not cater for the specific needs of the client.

As shown in Slide 1.12, integral analytical quality rests on unconditional acceptance of the basic standard (information requirements) in addition to classic tangible (e.g., potassium hydrogen phthalate) and intangible standards (e.g., official methods, ISO norms).

In summary, the analytical process should be designed in such a way as to ensure obtainment of the (bio)chemical information required, albeit with provision for additional but also important factors (see Slide 4.6).

This slide uses three examples to illustrate how the choice of the analytical process is dictated by the characteristics of the particular (bio)chemical information to be derived (e.g., the gold content of a batch, the quality of packaged milk and the glucose concentration of blood from a diabetic patient).

Example 1 requires maximizing accuracy, whereas Examples 2 and 3 require favouring the productivity-related analytical property expeditiousness at the expense of accuracy (see Slide 2.57 in Chap. 2).

Slide 9.33

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XVIII)

9.1.4.3. External connotations (III)

Potential sources of failure in SR in (bio)chemical information

2 Differences between delivering data, information or knowledge (1)

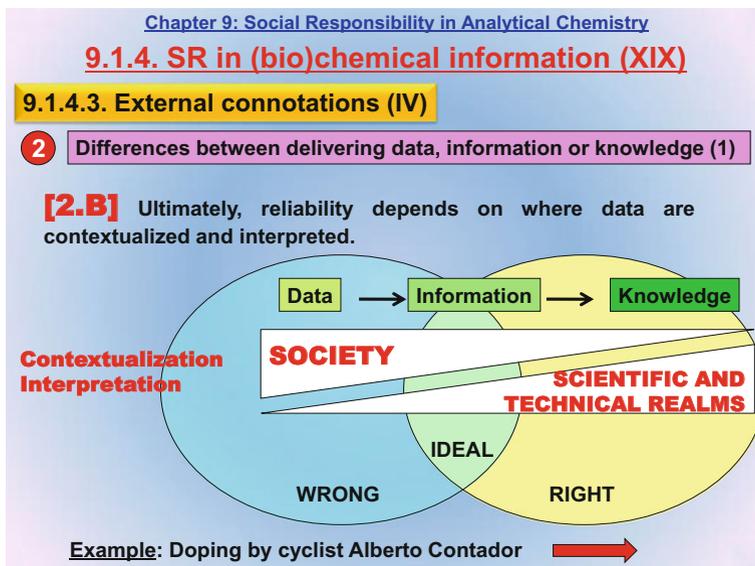
[2.A] Reliability depends on the type of “product” delivered

Data → Information → Knowledge

Reliability

The second major source of error in transferring (bio)chemical information to society arises from what the laboratory actually delivers (2A). In fact, supplying signals (data), results (information) or reports containing contextualized information (knowledge) is not the same. As shown here and in Slide 9.19, reliability increases from data to knowledge.

Slide 9.34



9.34.1. One additional, consequential source of distortion in the transfer of (bio)chemical information (2B) is where the information is contextualized and interpreted: society, or a scientific and/or technical area.

9.34.2. It is utterly wrong to directly deliver uninterpreted data (instrument signals) to society because most individuals lack the knowledge and training required to interpret them in a correct manner.

9.34.3. (Bio)chemical information should therefore be interpreted and knowledge in the analytical chemical realm produced by cooperating with other scientific and technical stakeholders.

Ideally, information should be contextualized and interpreted by scientists in collaboration with society.

9.34.4. The next slide illustrates the significance of who or where (bio)chemical information is converted into knowledge with the paradigmatic case of the alleged doping by cyclist Alberto Contador during the *Tour de France* in 2010.

Slide 9.35

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XX)

9.1.4.3. External connotations (V)

2 Differences between delivering data, information or knowledge (2)

Example: Doping by cyclist Alberto Contador

INFORMATION

↓

DIRECT, INCORRECT
TRANSFER TO
SOCIETY

↓

KNOWLEDGE

Result for a sample analysed by a laboratory using sophisticated equipment: 50 picograms of clenbuterol per millilitre.

Wrong conclusion →

DOPING BY THE WINNER OF THE TOUR DE FRANCE IN 2010: The media (particularly those outside Spain) published dramatic headlines.

IRREVERSIBLE DAMAGE: Contador found guilty by the Court of Arbitration for Sport (CAS)

CONTEXTUALIZED INFORMATION:

- Tolerated clenbuterol limit of the International Cycling Union much higher than the drug level measured in the cyclist's blood.
- The potentially large errors associated to low concentrations (Horwitz trumpet) were ignored ($\pm 30\%$ quite possible).
- Contador tested negative on previous and subsequent days.
- The most plausible explanation: eating contaminated meat (the "kiss theory" previously used to exonerate tennis player Gasquet).

9.35.1. While taking part in the Tour de France 2010, Alberto Contador was charged with drug abuse because his blood was found to contain a very small amount of clenbuterol as determined with sophisticated equipment only affordable by a few elite laboratories in the world at the time.

Directly transferring the result (information) to society led to the following unanimous interpretation outside Spain: Contador took drugs on a resting day during the race. The media published abusive headlines that inflicted serious moral damage on the cyclist and "compelled" the Court of Arbitration for Sport (CAS), based in Switzerland and also known as the "Tribunal Arbitral du Sport" (TAS) in French, to declare him guilty of doping. Directly delivering analytical information to society can thus have disastrous consequences (see Slide 9.23); in fact, the interpretation of an analytical result cannot be left to society at large or the media.

9.35.2. Had the analytical information been properly contextualized and interpreted in a report—which is what society should in fact have been delivered—society would have known that the clenbuterol concentration found in Contador's blood was below the International Cycling Union's tolerated limit, that very low concentrations are typically subject to very large errors, that the analysis was not replicated and that Contador tested negative for drugs on the previous and subsequent days. Most probably, the presence of clenbuterol was the result of the cyclist eating meat contaminated with this anabolic steroid (the analyte). Previously, French tennis player Richard Gasquet was exonerated of doping charges because he pleaded that the cocaine found in his blood was due to his kissing her partner, who was an addict at the time.

Slide 9.36

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XXI)

9.1.4.3. External connotations (VI)

Failure in the transfer of (bio)chemical information

Result with uncertainty

Binary response

Total index

Method-defined parameters

Others

[3.A] Undesirable extremes in the amount of information delivered

Excessive, superfluous information

Example 1

The EU tolerated limit of total hydrocarbons in potable water is 0.1 ppb.

A listing of aliphatic and aromatic hydrocarbon concentrations obtained with a conventional (slow, expensive) method will be useless.

A simplified extraction method can be used to obtain the total index required and expected.

Inadequate information

Example 2

The toxicity of water cannot be ascertained simply from the total concentration of mercury. Rather, it requires knowing the individual concentrations of all inorganic and organometallic mercury species because they differ markedly in toxicity.

9.36.1. The third major source of failure in transferring information to society has to do with the type of result (information) transferred, which may be a quantitative datum with its associated specific uncertainty (Chap. 2), a YES/NO qualitative response (Chap. 6) or a special form of information not dealt with in this book such as a global index for the total amount of members of an analyte family (e.g., total polyphenols in wine, total dioxins in ash) or a parameter (result) associated to the particular method used (e.g., soil extraction, where the specific ions extracted will depend critically on the leaching solution used).

There follow three different frequent situations that can be easily avoided.

9.36.2. The first (3.A) occurs when the information delivered is either excessive or deficient.

Delivering too much information (e.g., individual hydrocarbon concentrations when a total index would have sufficed) makes the process unduly costly and time-consuming; also, it can lead to the actual question (e.g., whether the total concentration sought complies with applicable legal limits) remaining unanswered. Similarly, delivering inadequate information (e.g., the total concentration of mercury in polluted water) may also leave the primary question (e.g., whether a river has been contaminated by mercury spillage) unanswered as a result of the actually required information (the presence and concentration of various mercury species differing markedly in toxicity such as Hg^{2+} , methyl-mercury and phenyl-mercury, for example) not being supplied.

Slide 9.37

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XXII)

9.1.4.3. External connotations (VII)

Failure in the transfer of (bio)chemical information

3 Dependence on the type of information to be delivered (II)

[3.B] Information (knowledge) with negative superfluous connotations.

Examples

1. **UNCERTAINTY** in quantitative results may elicit distrust in information receivers. It is preferable to use a concept with positive connotations: **A CONFIDENCE INTERVAL**.
2. **FALSE POSITIVES AND FALSE NEGATIVES** in Qualitative Analysis. It is preferable to use **PROPORTIONS OF HITS**.

The second situation (3.B) occurs when the information delivered possesses unnecessary negative connotations that may lead a receiver with inadequate scientific and technical knowledge to spurious conclusions (see Slider 9.39).

Thus, the *specific uncertainty* that should accompany a quantitative result can be taken to be the laboratory's degree of distrust in the information it is delivering. In the realm of Chemical Metrology, specific uncertainty can be replaced with a *confidence interval*; technically, the interval has the same meaning but is much easier to interpret by non-experts.

This is also the case with Qualitative Analysis (Chap. 6), where expressing reliability (a combination of accuracy and precision) in the form of false positives and false negatives can leave a bad impression on the information receiver. Why not replace them with the "proportion of hits" in the YES/NO binary response, which is one other way of defining reliability? Providing they retain some scientific and technical rigour, the results should be expressed in forms bearing positive connotations in order to boost the client's confidence in the delivering laboratory.

Slide 9.38

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XXIII)

9.1.4.3. External connotations (VIII)

Failure in the transfer of (bio)chemical information

3 Dependence on the type of information to be delivered (III)

[3.C] A need to complete typical (bio)chemical information.

Example

How can uncertainty in a binary response be expressed? It requires imagination in order to replace with the classical concept with a “concentration interval” around the limiting concentration where a given proportion of errors is made.

**BREAK WITH TRADITION
IN CLASSICAL METROLOGY**

9.38.1. In the third situation (3.C), the information transferred is inadequate and should be completed.

Such is the case with uncertainty in the YES/NO binary response in Qualitative Analysis. How can an interval around a YES/NO response be expressed in familiar terms? This obviously entails replacing established knowledge with imagination (see Slide 9.9) to conceive new concepts such as the concentration range around a limiting concentration at which an acceptable proportion of errors in terms of a statistical probability level can be expected.

9.38.2. This example illustrates the need to break with tradition in Classical Metrology whenever required to solve a specific analytical problem (see Slide 7.12, Sect. 7.4).

Slide 9.39

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XXIV)

9.1.4.3. External connotations (IX)

Failure in the transfer of (bio)chemical information

4 Technical expertise of the information receiver

● The greater the receiver's expertise, the more likely success in the transfer and in the ensuing decision

A chemist with expertise in the problem

An expert in the problem

An expert chemist

An official (politician, economist) with a basic scientific and technical background

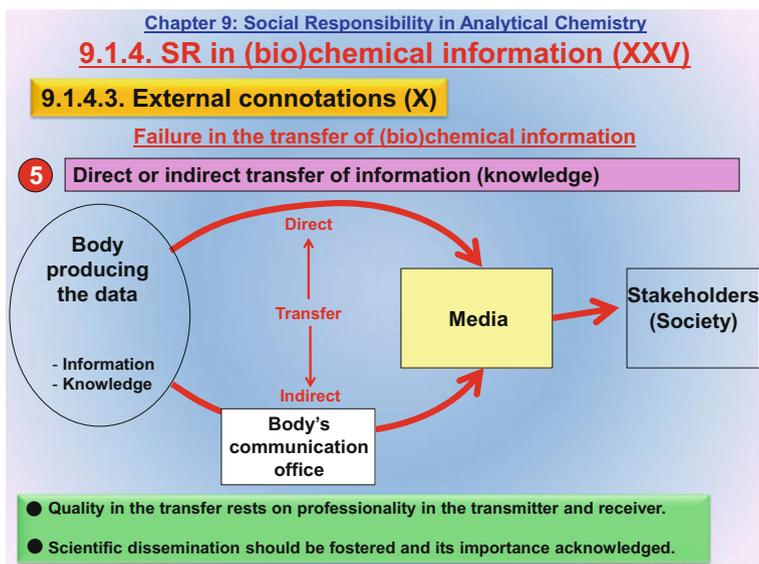
An official (politician, economist) lacking a basic scientific and technical background

The nature of the receiver is crucial for correct transfer and interpretation of (bio)chemical information from a laboratory. The greater the receiver's experience is the more likely will be correctly understanding the information delivered.

The difficulty increases from a receiver being a scientist (e.g., an analytical chemist) with experience in the type of problem addressed to a judge, politician or corporate executive with no scientific or technical background. The slide shows various situations in between these two extremes.

As the difficulty grows, the results (information) should be converted into increasingly well documented reports.

Slide 9.40



9.40.1. The fifth source of distortion in the transfer of (bio)chemical information is its direct or indirect nature.

In direct transfers, the laboratory's parent body—or the laboratory itself if entitled—issues not only results, but also reports for the media to be conveyed to society. Obviously, the media should disseminate the information they receive with Social Responsibility (for example, with alarming or appealing rather than factual headlines).

9.40.2. Indirect transfer can be done through the communication office of the laboratory's parent body, which should obviously act socially responsibly in order to avoid distortion of the (bio)chemical knowledge it transfers.

9.40.3. Proper transfer rests on ethical conduct in both the organs conveying the information (that is, information producers) and those receiving it (information receivers and disseminators). Also, scientific dissemination should be strongly boosted through appropriate training and recognition.

Slide 9.41

Chapter 9: Social Responsibility in Analytical Chemistry
9.1.4. SR in (bio)chemical information (XXVI)

9.1.4.3. External connotations (XI)

Failure in the transfer of (bio)chemical information

6 **Impact of (bio)chemical information**

- The importance of (bio)chemical information delivered depends on its significance and consequences.
- The analytical process should be designed with provision for the potential impact of the analytical information to be produced.

Examples

HIGH IMPACT	HIGH IMPACT	MEDIUM IMPACT
<ul style="list-style-type: none"> ▪ Alcohol in blood as the cause of a road accident. <p style="text-align: center;">↓</p> <ul style="list-style-type: none"> ▪ A few tenths in the result may lead to years in prison. 	<ul style="list-style-type: none"> ▪ Analysis of a batch of several tons of dried fruits potentially containing aflatoxins. <p style="text-align: center;">↓</p> <ul style="list-style-type: none"> ▪ A false negative may lead to cancer in the fruit consumers. 	<ul style="list-style-type: none"> ▪ Pricing feed in terms of moisture content. <p style="text-align: center;">↓</p> <ul style="list-style-type: none"> ▪ An error in moisture content can lead over- or underpricing.

9.41.1. The potential importance and impact of (bio)chemical information transfer should always be considered.

9.41.2. Thus, the analytical process should be suited to the strength of the predicted impact. This slide exemplifies three different situations.

- (1) One case where (bio)chemical information can have a strong impact is the determination of alcohol in blood from individuals involved in a road or work accident. A few tenths in a result can lead to several years in prison. Also strong can be the impact of the results of a screening (qualitative) analysis of a batch of imported dried fruits potentially containing aflatoxins. A false negative (Slide 6.22) may lead to carcinogenic effects on consumers. In this situation, it is crucial to analyse the fruits with a proven, validated method.
- (2) A lesser impact of (bio)chemical information is to be expected from inaccurate measurements of feed moisture; in fact, a positive or negative error can lead to the feed being under- or overpriced, respectively, but not to deleterious effects on cattle. Therefore, direct, non-destructive analysis with, for example, a near-infrared (NIR) probe can suffice to set a fair price despite the likely errors in the measurements.
- (3) Finally, using an analytical method with a limit of detection well below the critical concentration (e.g., toxic level) of an analyte in a given type of sample can have little unfavourable impact on the (bio)chemical information derived.

Slide 9.42

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XXVII)

9.1.4.3. External connotations (XII)

Failure in the transfer of (bio)chemical information

7 External manipulation of the information (1)

- Interested alteration of the information by the receiver (or an associated stakeholder) involving **manipulating samples** by introducing extraneous substances to obtain the spurious results wanted.
- Samples can be manipulated in two different types here:
 1. By fraudulently introducing the analyte so that the sample will be erroneously qualified.

Example: Adding hydrocarbons to spring water in order to have the spring discarded for spurious interests.
 2. By fraudulently introducing a harmless substance to have it interact with the analyte or system in order to mask the analyte.

Example:

 - Adding substances to mask drugs of abuse analysed in sports doping tests.
 - The substances are banned by international bodies such as IOC or ICU.
 - Purpose: a) Facilitate fast release (diuretic).
b) Alter analyses (through negative interferences).
 - Tour de France 2011:
Russian cyclist Alexander Kolounev was expelled because he tested positive for the diuretic HYDROCHLOROTHIAZIDE, which facilitates the release of anabolic steroids.



The last source of failure in transferring (bio)chemical information is fraudulent manipulation of the target sample or system under study by the receiver prior to submission to the laboratory.

The source of error in this case is the deliberate addition of one or more substances to alter the original sample for spurious purposes—usually increasing the value of a commercial product. Obviously, the information received from the laboratory will be erroneous.

The target analyte can be added to the sample for two different purposes, namely:

1. To have its concentration exceed legally tolerated limits and the sample be incorrectly deemed toxic (e.g., deliberately adding hydrocarbons to spring water to have it discarded for spurious reasons).
2. To have an added substance interact with the analyte or its moiety in order to reduce its concentration to undetectable levels (a fraud). The slide shows a typical example of drug abuse in sports. Some bodies such as the International Olympic Committee (IOC) and the International Cycling Union (ICU) have their own lists of banned substances that they are not drugs.

The next slide elaborates on the second example.

Slide 9.43

Chapter 9: Social Responsibility in Analytical Chemistry
9.1.4. SR in (bio)chemical information (XXVIII)

9.1.4.3. External connotations (XIII)

Failure in the transfer of (bio)chemical information

7 External manipulation of the information (2)

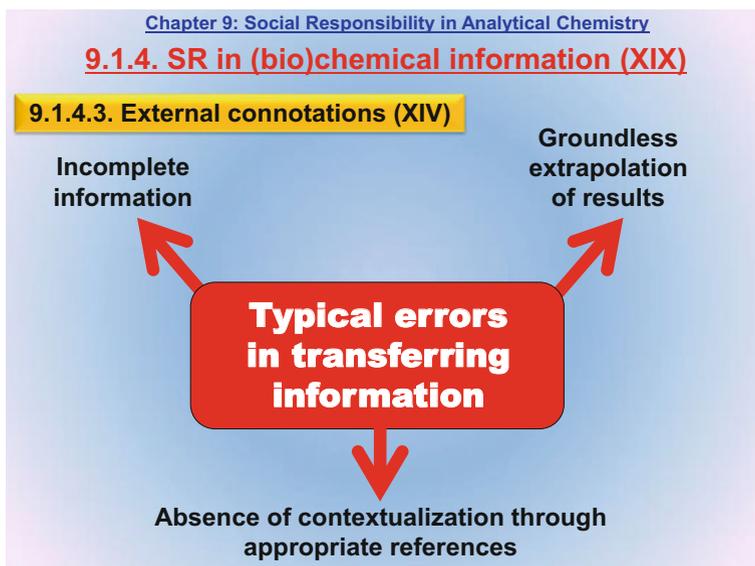
2. Fraudulently adding a harmless substance interacting with the analyte or system to mask the analyte.

Example:

- Adding substances to doping test samples in order to mask abuse drugs.
- Substances banned by international sports bodies such as IOC or ICU.
- Purpose: (a) Facilitate rapid release (diuretics).
(b) Alter analyses (through negative interferences).
- **Tour de France 2011:**
Russian cyclist Alexander Kolounev was expelled because he tested positive for the diuretic HYDROCHLOROTHIAZIDE, which helps remove anabolic steroids.

As can be seen, spuriously added substances (second example in Slide 9.42) can act in two different ways, namely:

- (a) By facilitating the fast release of drugs (for example, with diuretics), as in the case of doping in the Tour de France.
- (b) By introducing a negative interference with the analytical process to, for example, facilitate retention of a drug (the analyte) on a sorbent in order to avoid its detection—and potential consequences—as a result.

Slide 9.44

This is a brief summary of the three commonest errors in transferring (bio)-chemical information.

9.44.1. Delivering incomplete information that will lead to a wrong decision.

9.44.2. Misinterpreting results—and extrapolating them wrongly, for example.

9.44.3. Using no appropriate references to contextualize information in reports. It is knowledge rather than information or results that should be transferred.

Slide 9.45

Chapter 9: Social Responsibility in Analytical Chemistry

9.1.4. SR in (bio)chemical information (XXX)

9.1.4.3. External connotations (XV)

SELECTED EXAMPLES OF UNFORTUNATE TRANSFER OF
(BIO)CHEMICAL KNOWLEDGE

DRUGS OF ABUSE IN ENVIRONMENTAL SAMPLES

NEWSPAPER	DATE	HEADLINE
PÚBLICO	13/05/2009	In Madrid and Barcelona, the air contains cocaine
LA RAZÓN	14/05/2009	Madrid and Barcelona breathe 5 different drugs
LA NUEVA ESPAÑA	14/05/2009	White dust over Madrid and Barcelona
ALERTA	23/09/2010	Cocaine found in La Albufera
EL DIARIO VASCO	29/10/2009	Cocaine present even in tap water
LA RIOJA	04/10/2009	An official study concludes that each inhabitant of Logroño takes more than 0.5 kilograms of drugs everyday

This slide shows sensationalistic headlines published by various Spanish media that misinterpreted anecdotal results of drug determinations in air and water.

The most serious problem with the resulting alarmism was that it was caused by the communication offices of public or private bodies seeking popularity. Such offices were directly responsible for the analyses and hence for avoiding these relatively common errors in transferring (bio)chemical information given the—presumed—scientific and technical background of their members.

9.2 Annotated Suggested Readings

PAPERS

Scientific social responsibility: A call to arms

P. Krogsgaard-Larsen, P. Thostrup and F. Besenbacher
Angewandte Chemie Int., 2011, 50, 2–4.

This is a short, brave, somewhat provocative but realistic paper written by three highly renowned European scientists that emphasizes the significance of Social Responsibility in Science and Technology in the XXI century.

Social responsibility in Analytical Chemistry

M. Valcárcel and R. Lucena
Trends Anal. Chem., 2012, 31, 1–7.

This paper constitutes the backbone for the present chapter and deals with virtually all of its contents.

Teaching social responsibility in Analytical Chemistry

M. Valcárcel, G.D. Christian and R. Lucena

Analytical Chemistry, 2013, 85, 6152–6161.

This paper describes strategies for teaching Social Responsibility in Analytical Chemistry. Its contents overlap with those of this chapter.

BOOKS**Handbook of Green Analytical Chemistry**

M. Guardia and S. Garrigues (Eds)

Wiley, New York, 2012.

This book discusses the first facet of the internal connotations of SR in Analytical Chemistry and available choices for making analytical laboratories sustainable.

9.3 Questions on the Topic (Answered in Annex 2)

9.1. Relate SR in Analytical Chemistry to

- analytical quality (Chap. 8); and
- analytical problem-solving (Chap. 7).

9.2. What are the keywords defining Social Responsibility? Which are especially significant because they are shared by many definitions of SR?

9.3. Define “stakeholders” in the context of SR, and of ISO guides and norms.

9.4. Describe the cycle of concepts that provides an integral definition of SR in an individual, an organization and a scientific or technical area.

9.5. Highlight four of the five principles governing SR. Which is the most important? Why?

9.6. Can marketing SR be

- (a) positive?
- (b) negative?
- (c) neither positive nor negative?

Justify your answer.

9.7. What is the most important link in the cyclic succession of SR concepts? Why is it more important than the others?

9.8. Are the following statements true or false?

- (a) Ethical principles encompass SR.
- (b) Implementing SR in a scientific or technical area encompasses quality systems.
- (c) For many organizations and businesses, SR is merely a window-dressing opportunity.

Justify your answers.

9.9. Why are SR in Analytical Chemistry and SR in (bio)chemical information equivalent?

9.10. What are the internal and external connotations of SR in (bio)chemical information? Are they related in any way? How?

9.11. Explain the differences between the transfer of data (signals), results (information) and reports (knowledge) to society.

9.12. Which of the three sources of distortion in the transfer of (bio)chemical information is the most important? Rank them according to significance.

9.13. Are the two internal connotations of SR in Analytical Chemistry related? Which is the more important? Why?

9.14. What is the difference between the two models of quality in (bio)chemical information (the second facet of external connotations of SR in Analytical Chemistry)?

9.15. Why can the type of information delivered be important with a view to facilitating effective communication between analytical laboratories and clients requiring information?

9.16. Can using a communication office to deliver information from a laboratory have a positive effect on the parent body? Why?

9.17. How is the choice of an analytical process dictated by the potential impact of the (bio)chemical information to be delivered?

9.18. Explain the sentence “quality in information transfer depends on both the producer and the receiver of the information”. Discuss the significance of the information required by the receiver.

9.19. How important can experience in the dissemination of science be to transfer (bio)chemical information? Why?

9.20. How can SR in Analytical Chemistry be assured?

9.21. Explain the “transparency principle” supporting SR in Analytical Chemistry.

9.22. Describe the two main ways in which a sample can be tampered with in order to have it give spurious results for fraudulent purposes.

9.4 An Abridged Version of the Chapter

The contents of this chapter can be shortened by about one-half for teaching Analytical Chemistry to students not majoring in Chemistry. The slides to be omitted for this purpose are as follows:

- Section 9.1: Slide 9.3.
- Section 9.2: Slides 9.6–9.9 and 9.13.
- Section 9.3: Slides 9.14 and 9.15.
- Section 9.4: Slides 9.18, 9.19, 9.21–9.23, 9.28, 9.29, 9.44 and 9.45.