# Editorial

# Social responsibility in analytical chemistry

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We approach social responsibility (SR) in analytical chemistry (SRAC) systematically for the first time. Although this is not a new topic, it has scarcely been referred to under this designation. This Editorial discusses both internal [sustainable production of reliable (bio)chemical information] and external [transfer of (bio)chemical knowledge to stakeholders] connotations of SRAC. It can be regarded as a contribution to SR of chemistry (SRC) and the transmission of scientific and technical information. The aim of this Editorial is to stimulate consideration of SR as one of the cornerstones of our discipline as well as to encourage the participation of the analytical chemistry (AC) community in building the SRAC concept.

SR is a topic of growing interest not only for public and private bodies, but also for virtually any human activity with a direct impact on society. However, the SR concept is far from new, as it emerged in the business realm in the mid-twentieth century. Publication of the book ''Social Responsibility of the Businessman'' by H.R. Bowen is considered to be the origin of formal writing on this topic [1]. Bowen's original thoughts were later enriched by the evolution of social thought [2]. The generic concept originally defined in 1953 has been infused with various nuances of meaning involving environmental and work-safety considerations, among others. Essentially, SR is a rich concept admitting multiple interpretations to judge by its many definitions [3]. Current definitions of SR include positive and negative connotations describing ''active'' and ''passive'' views of the concept. The passive view holds that the ultimate aim of SR is to reduce the adverse social impact of a given area of human activity; by contrast, the active view sees SR as a means of improving society.

The SR concept was initially restricted to the corporate world and termed ''corporate social responsibility'' [4]. This traditional view remains, so SR is frequently used in connection with marketing and competitive strategies to show social awareness and arouse positive feelings about a firm. However, the concept is now used in a wider context, including a number of human activities and areas. Such is the case with chemistry, which is in great need to improve its poor social image by emphasizing its undoubtedly positive contributions to human well-being. This was one of the primary goals of UN, UNESCO and IUPAC in declaring 2011 as the International Year of Chemistry [5]. In parallel, the term SRC has grown in use in the scientific and technical literature to refer to, mainly, green-chemistry processes [6]. Also, IUPAC sponsored an SRC project aimed at disseminating new educational means to support sustainable development, among other goals [7].

One of the essential aspects of SR is communication, which experts have deemed the Achilles' heel of SR management. SR in science and technology is confronted with the challenge of bridging the large gap between science and the public [8], which has probably grown as the result of scientists traditionally failing to explain the social implications of their findings properly. The usefulness of scientific activities cannot be exclusively assessed in terms of scientometric indicators; rather, efficient scientific and technical management bodies, and press departments, are needed to establish a solid framework for linking scientific advances to social

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perception. No doubt, the media can play a crucial role in this venture [9,10].

Although SRAC is a part of SRC, it has some special connotations regarding the production and the dissemination of (bio)chemical information or knowledge in and from analytical laboratories to society at large. The ethical issues in relation to collection, processing, interpretation and reporting analytical data are well established in some contexts (e.g., clinical chemistry) {e.g., the specific role of SRAC has been acknowledged by the Asian Analytical Chemistry Network [11]}.

This Editorial discusses SRAC in terms of the relationships between analytical science and two prominent international written standards. As shown below, SRAC cannot be properly defined without contextualizing analytical information and knowledge in the framework of a general hierarchy and formulating new practical targets for AC. As also shown here, internal (passive) and external (active) connotations of SRAC materialize in the production and the transfer of analytical information and knowledge.

## 1. Cornerstones of social responsibility in analytical chemistry

SRAC can only be properly exerted with the support of the three cornerstones of analytical science, namely written standards, (bio)chemical information and future targets.

SRAC can be supported by two written standards that are directly connected with SR [12] and knowledge management [13], use of which must be extrapolated from the corporate realm to the scientific and technical realms. AC can benefit from the philosophy behind those standards to develop a solid framework for internal organization and external relationships with stakeholders. Likewise, AC can help other scientific and technical activities accomplish SR principles by providing quality (bio)chemical information and developing new, ''clean'' methods of analysis [14]. Similarly, AC can benefit from the philosophy behind knowledge-management guidelines [13] by using them to establish a technical framework to support its primary outputs.

AC is an information discipline whose ''products'' can be contextualized by placing them in a data–information–knowledge hierarchy (e.g., Fig. 1) with reference to their counterparts in the chemistry domain. The primary data are the signals provided by instruments in the second step of the analytical process. Their compilation and calculation allows one to obtain so-called ''results'', which correspond to ''information'' in the hierarchy. Finally, analytical information can be processed, interpreted and contextualized to produce so-called ''reports'', which correspond to ''knowledge'' in the hierarchy, and provide support for decision-making, hypothesis formulation and mechanism elucidation. At the top of the hierarchy lies ''imagination'', which, according to Albert Einstein, facilitates the creation of new paradigms and the breaking of traditional barriers.

The general and specific objectives of AC, which have remained well defined and established for centuries, have lately evolved at such a brisk pace that a completely new scenario for this discipline is currently under development and construction. This is one of the cornerstones of a new approach to AC – relying on the gradual establishment of new analytical targets, the most salient of which were proposed recently [15].

## 2. Definitions of social responsibility in analytical chemistry

The general definition of SR cannot be directly transposed to another human activity without considering its intrinsic nature, so any definition of SR in the AC domain should consider the intrinsic nature of this discipline. Broadly, AC can be defined as a scientific discipline that develops and applies methods, instruments and strategies to obtain quality (bio)chemical information on the composition and nature of matter in space and time [16]. Therefore, an appropriate definition of SRAC should consider its twofold mission:

(1) AC produces quality (bio)chemical information intended to facilitate resolution of a real-life problem; and,
(2) the procedures used to meet this requirement should have a minimal impact on operators and the environment.

The evolution of AC over the past 20 years suggests increasing consideration of SR in relation to the latter aspect. Thus, automation, simplification and miniaturization, which are the three greatest driving forces of AC development, are intended to reduce the environmental and health impact of analytical procedures. Automation alleviates the adverse effects of AC on operators by reducing their involvement in some hazardous steps of the analytical process. Similarly, simplification and miniaturization reduce the impact of AC on the environment by decreasing the use of resources and the production of waste.

Although the latter aspect of SRAC has enjoyed intensive development in recent years, the dissemination of information, which is essential to the former aspect, has been considered in a much narrower framework. Analytical chemists should fill the existing gap between the general public and their discipline by disseminating information in a straightforward, ethical way. We deal with this requirement in depth below.

The discussion has so far revolved around the passive approach to SRAC, which focuses on reducing the adverse social impact of AC. A richer concept of SRAC can be established by also considering the positive role

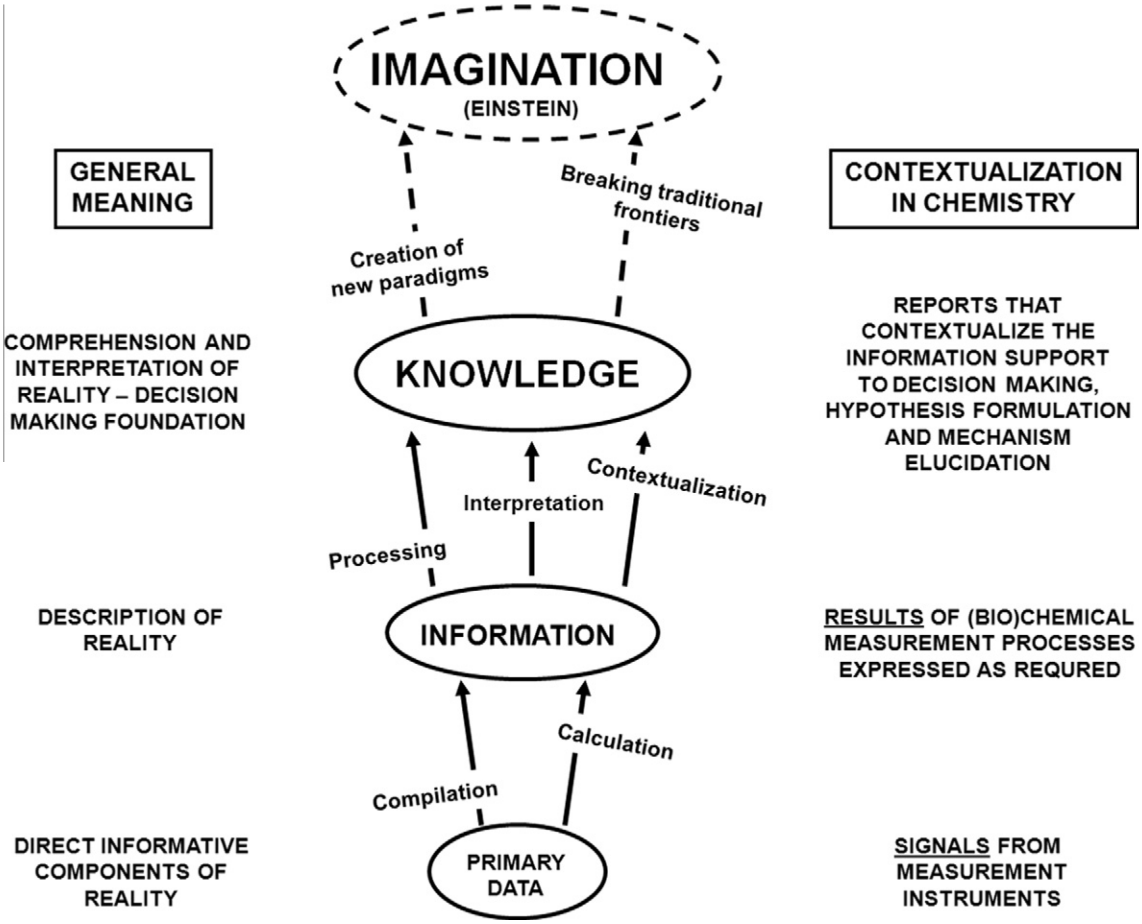


**Figure 1.** General meaning and adaptation of the data--information--knowledge--imagination hierarchy to the chemical domain.

(active approach) that this scientific discipline can play. Some AC activities with a positive social impact are directly or indirectly related to the way (bio)chemical information is disseminated, as it is the case of medicine (blood analysis), pharmaceutical industry (quality control) or engineering (chemical analysis and characterization of new materials).

Fig. 2 depicts SRAC as a combination of SR of chemistry (SRC) and dissemination of science and technology. SRAC is grounded on the three previous concepts, namely:

(1) the new targets for AC;
(2) written norms and guidelines; and,
(3) the data–information–knowledge hierarchy.

Accordingly, SRAC can be defined as ''the ethical conduct of analytical chemistry procedures to provide quality (bio)chemical information with as little impact on operators and the environment as possible with a view to solving real-life problems efficiently – with adherence to the fitness-for purpose principle – and ultimately improving citizens' quality of life''. In other words, SRAC includes the impact and the ethical principles of AC as a profession.

## 3. Sustainable production of quality (bio)chemical information

This constitutes the intrinsic–passive aspect of SRAC in Fig. 3, which is concerned with the development, optimization, validation and application of (bio)chemical measurement processes to obtain primary data and results. The key attributes of this facet of SRAC are ''sustainability'' (of the analytical procedures) and ''quality'' (of the (bio)chemical information generated).

This intrinsic responsibility of AC implies ethical demand to develop analytical processes optimally by using analytical tools (i.e. instruments, devices, reagents, solvents, reference materials) of increasing quality to produce results intended to solve efficiently the analytical problems posed by (bio)chemical information requirements. This entails ensuring ''fitness for purpose'', a well-established concept in the validation of analytical methods, that requires flexible implementation and due consideration of the current targets of AC in some instances. One case in point is the episode of massive contamination by dioxins in chicken meat in Belgium in 1999, when the ISO standard applicable proved inefficient, since its procedures were time con-

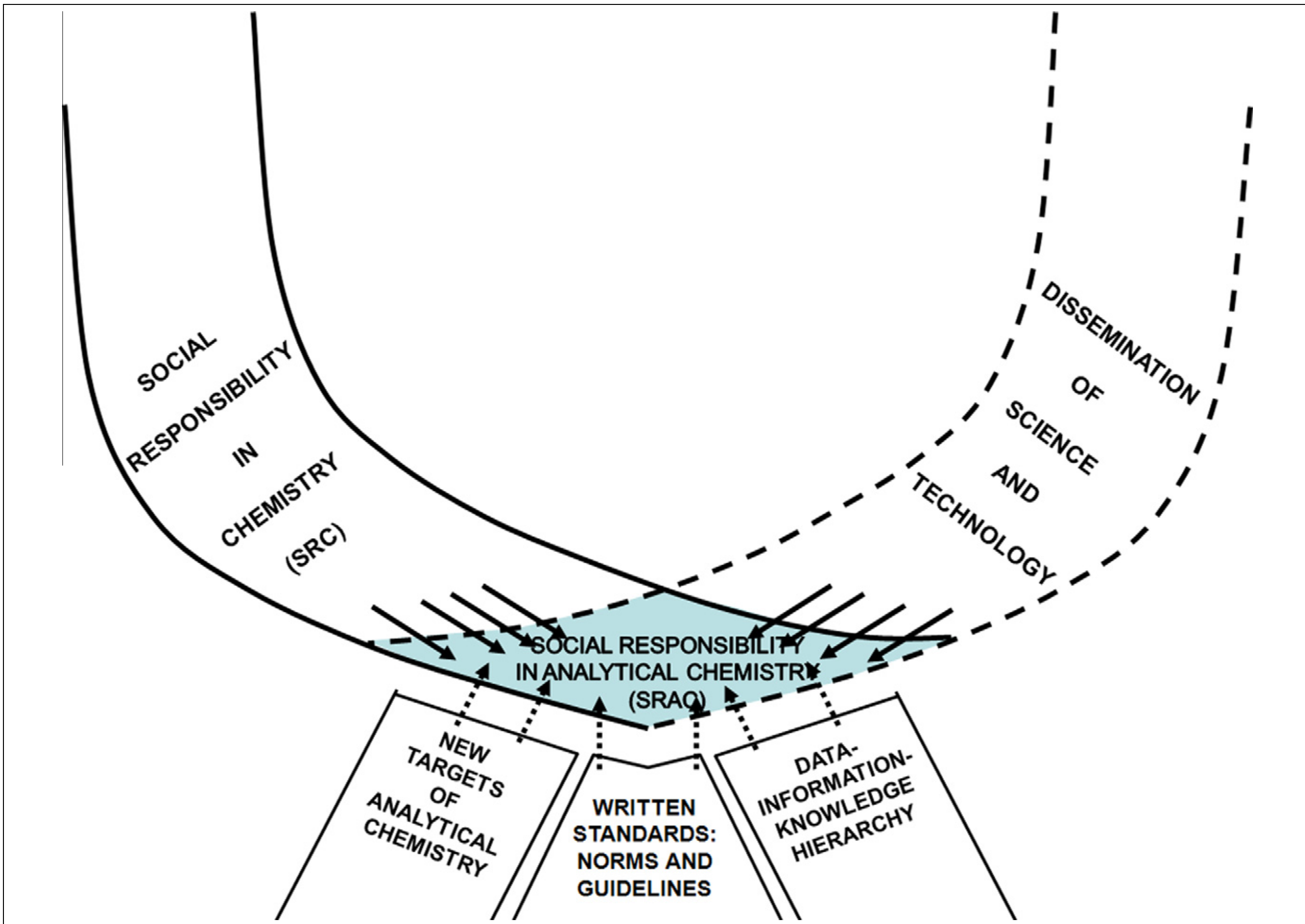


**Figure 2.** Definition of social responsibility (SR) of analytical chemistry (SRAC) as a combination of SR of chemistry (SRC) and the dissemination of science and technology. The cornerstones of SRAC are also shown.

suming and the number of samples to be analyzed grew exponentially during the critical days. A new, rapid alternative method was therefore required to solve the social problem.

One of the major technical trends in the production of data and results by analytical laboratories at present is minimizing or avoiding their contribution to environmental pollution by producing as little waste as possible (reagents, solvents, gases). So-called ''green analytical methods'' [14], a detailed description of which is beyond the scope of this Editorial, constitute an essential element of meeting the intrinsic targets of SRAC.

As can be seen from Fig. 3, it is arguable whether analytical signals and results should be directly delivered or pre-processed to produce analytical knowledge potentially more useful for solving real-life problems. The answer is not easy and depends on a number of factors including:

(1) the technical expertise of the information receiver, who may be a scientist, a technician, a judge, an economist, a civil servant or simply a member of the public;
(2) the type of information to be provided (e.g., qualitative data and their associated uncertainty intervals, a binary response, a total index, or a method-defined parameter), which may not be easy for the public to understand; and,
(3) the significance or potential impact of the results.

For example, a binary response is easier to understand than a quantitative result, but delivering a single quantitative datum can lead to misinterpretation of the results, as was the case with the dissemination by the media that the 2010 Tour of France winner had tested positive for clembuterol simply because a test had detected a very low concentration of this banned substance in his blood. This led to the immediate, wrong social inference that the cyclist had doped. Also, ignoring the limits set by international agencies led the media to contrive a highly negative, unfair public image of the suspect sportsman.

Some strategies are used to manipulate this intrinsic facet of SRAC for spurious purposes. In this sense, the use of specific substances may negatively affect the production of reliable data. This is the case of the

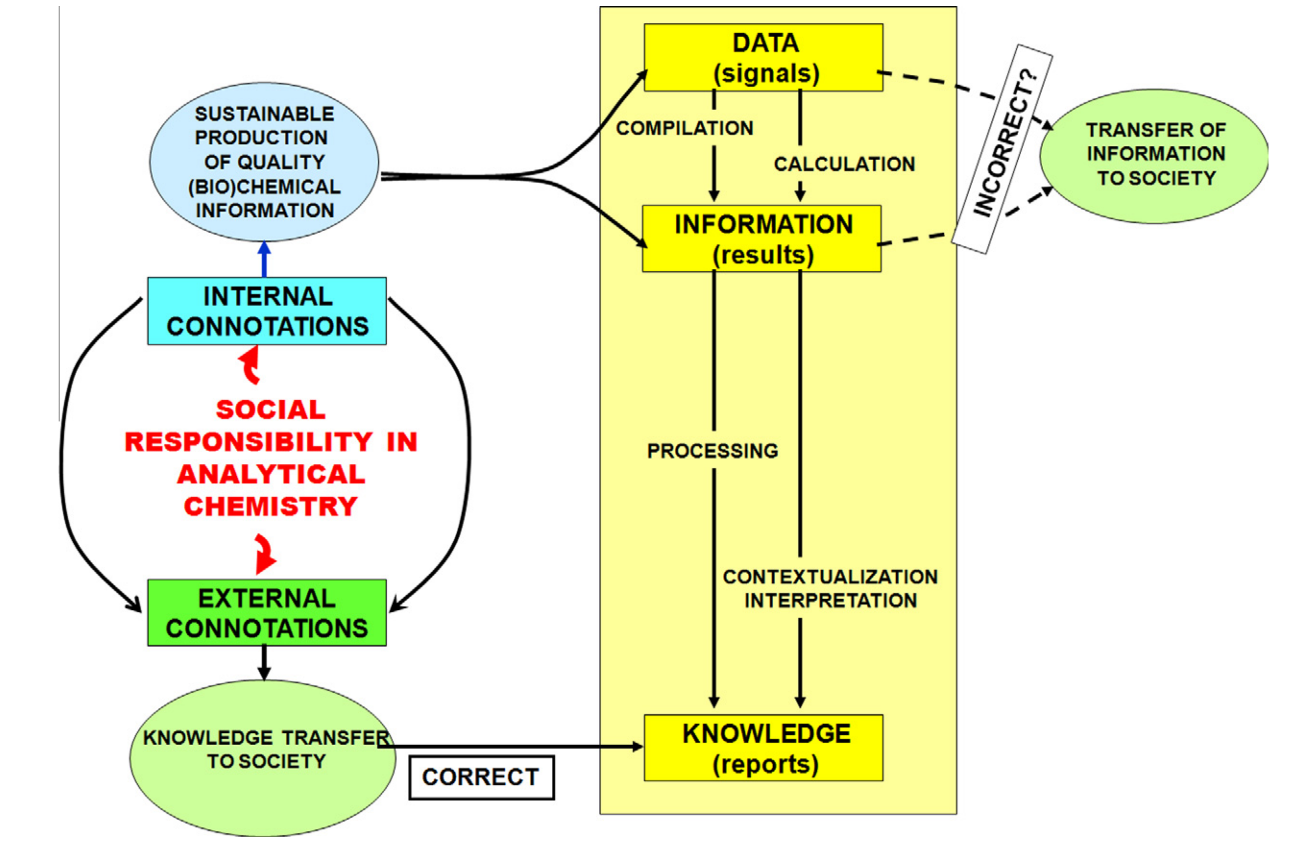


**Figure 3.** Internal and external connotations of social responsibility in analytical chemistry (SRAC), and their relationships with the data--information--knowledge hierarchy. For details, see text.

masking substances (also considered illicit drugs by the International Olympic Committee) used by some athletes to interfere with the determination of doping agents in urine and blood.

## 4. Transfer of analytical chemical knowledge

Exerting SR requires highly efficient communication between the partners involved in a given human activity. Properly disseminating scientific knowledge and technological advances is a crucial, but occasionally utopian, objective in the scientific domain. Disseminating scientific findings in developed countries is essential for two different, seemingly complementary, reasons. Thus, scientific education can be beneficial to virtually all citizens by improving their quality of life in this increasingly ''technological world''. In addition, a sizeable fraction of scientific research is supported by public funding, so scientists should be accountable to taxpayers for their expenses and results [17].

In the past few decades, the relationship between science and society has been the focus of extensive analysis [18] and controversy. Although a perfectly synergistic relationship between science and society would be desirable, connecting the two is usually difficult. Thus, some surveys have shown that most citizens, even in developed countries, are scarcely interested and/or educated in science. Also, scientists usually speak a strange, obscure language that hinders fluent communication with the public. The scientific community should therefore make a strong effort to reduce this gap. As stated by Albert Einstein: ''If you cannot explain it simply, you do not understand it well enough''.

Scientific dissemination is not highly valued among scientists because it awards no bibliometric ''marks''. Scientists tend to disseminate their research findings in highly specialized journals that are inaccessible to the general public and even to other scientists working in other fields of study. Moreover, science lacks public literacy [8], which can only be achieved with the help of the general and public media. Public media seem a strange environment to scientists inasmuch as they pursue different – though not necessarily less worthy – goals. Scientists and journalists may differ about what is ''interesting'' or ''important'', and this can lead to sensationalistic headlines [19] or even incorrect information [20] grossly departing from the essential goal of disseminating accurate scientific knowledge. Carrada's book ''Communicating science: a scientist's survival kit'' can be a useful source of ideas for any scientist interested in effectively disseminating their research among the general public [21].

As a scientific discipline, AC stands in the scenario described above. Also, because AC is (bio)chemical information science and its output can have social implications, it bears additional responsibility in this context. Thus, AC should provide quality analytical information in order to facilitate resolution of a real-life problem with adherence to the fitness-for-purpose principle. This requires support for the delivery of information conforming to appropriate standards and contextualizing it in an appropriate manner to avoid potential misunderstandings. Transfer of (bio)chemical information can fail as a result of:

(1) Incomplete information being delivered. For example, if an environmental sample is analyzed for potential contamination with lead, the total amount of lead present in it is probably not the best information one can provide. The toxicity of lead depends on its particular chemical state (e.g., whether or not it is bound to organic matter). In this situation, information about the different species of lead present in the sample concerned can be more useful for the intended purpose.
(2) Results being extrapolated without proper contextualization. Finding traces of drugs in environmental samples should not lead to the conclusion that we are taking drugs when we have a pleasant bath.
(3) Analytical information not being properly contextualized in relation to applicable references. Detecting a drug in a sportsman's blood test does not mean he has doped unless the datum is accompanied by the allowed concentration limit for the drug and this threshold has been exceeded in the particular sample.

All connotations of SRAC, as illustrated in Fig. 3, should therefore be considered to ensure proper dissemination of (bio)chemical information. Relating to media is a necessary, but difficult step, especially for ''beginners'' in this new scenario. As in a typical science communication, the scientist should be involved in the publication process in order to propose any necessary corrections and to check that the information eventually disseminated is accurate.

## 5. Concluding remarks

AC should be permeable to social trends to improve human activities continually. One such trend is SR, which should no longer be the exclusive concern of corporations. The social impact of sciences has increased over the past few decades, but has scarcely been approached in a systematic manner under the umbrella of general SR.

Systematically incorporating SR into analytical science is bound to afford the harmonised consideration of issues that are ordinarily dealt with separately (e.g., green methods of analysis or the production of quality of (bio)chemical information from analytical processes). The recent incorporation of the stakeholders' (bio)chemical information requirements as a third basic standard in addition to the classical (tangible and intangible) standards has emphasized the active role of SRAC in meeting such information needs via the transfer of knowledge in the form of useful reports.

SRAC can be approached in a passive or active manner. In the passive approach, AC is devoted to provide quality (bio)chemical information with a minimal impact on operators and the environment. In the active approach, analytical information (knowledge) should facilitate educated, expeditious decision-making, leading to improved living standards.

The topic of this Editorial is not really new, apart from our systematic approach to our three-fold aim, namely:

(1) to emphasize the importance of SRAC;
(2) to promote its use in order to support a new view of AC consistent with social and scientific trends; and,
(3) to improve the current image of AC in order to meet one of the main objectives of celebrating 2011 as the International Year of Chemistry [5].

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