

INTERVIEW



Joanna Szpunar ^{iD}, an outstanding chemical researcher in the chemistry of metal-biomolecule interactions, shares her experience as a woman scientist with BrJAC

Joanna Szpunar graduated from the Warsaw University of Technology in 1986 and obtained her Ph.D. (1992) and D.Sc. (Habilitation) (2000) from the University of Warsaw. Since 1997, she works at the National Research Council of France (CNRS). In 2007, she obtained in Poland the title of professor of chemistry. She has broad experience in the field of mass spectrometry-based bio-inorganic speciation analysis and metallomics with a focus on the identification and quantification of trace element species in biological systems and in the chemistry of metal-biomolecule interactions. She is the co-author of a book and approximately 250 scientific publications in peer-reviewed international journals.

Joanna Szpunar is a fellow of the Royal Society of Chemistry (UK) and has been, for many years, a member of the boards of *Journal of Analytical Atomic Spectrometry* and *Metallomics*. She regularly gives invited lectures at international analytical chemistry meetings and was the chairperson of the European Winter Conference on Plasma Spectrochemistry (Kraków, Poland) in 2013.

The investigations carried out under her supervision and/or with her active participation resulted in the identification of a number of molecular targets of metals in biological systems, as well as contribute to selenometabolomics and selenoproteomics studies in bacteria and plants. In recent years, her interests were broadened to the environmental fate of metal-containing nanoparticles and nanoplastics. She has supervised 12 Ph.D. theses and several post-doctoral fellows.

Joanna Szpunar is the laureate of the 2013 Jerzy Fijalkowski Award of the Committee of Analytical Chemistry of the Polish Academy of Sciences and the 2017 European Award for Plasma Spectrochemistry.

In recent years, Joanna Szpunar has been involved in collaboration with analytical chemists in Brazil, hosting graduate students from the University of Campinas and the Federal University of Pelotas in the laboratory at the Institute of Analytical Sciences (IPREM) in Pau affiliated with the CNRS, lecturing at the Federal University of Santa Maria and co-supervising a Ph.D. student with work carried out at the University of Pau and the Federal University of Pelotas.

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BrJAC: Which factors influenced your education? When did you decide to study chemistry? What motivated you? How was the beginning of your career?

Dr. Szpunar: Chemistry has been present in my life since the very beginning. My mother was a high school chemistry teacher and my father a researcher and university professor in materials science, so I was exposed to different notions of chemistry very early. So, in my case, there was no sudden light bulb revelation but rather a gradual process of subconscious learning. Quite naturally, maybe because I was an only child, I was intrigued by what my parents were doing and step by step it led me to getting closer to this field and finally choosing it for my personal career.

At the same time, I must confess that for quite a period I was inclined to go towards literary studies (I have always been an avid reader) but finally opted for a technical university. My *Alma Mater* is Politechnika Warszawska (the Warsaw University of Technology) which is considered the leading technical university in Poland. My first choice was materials science and my M.Sc. work was focused on the synthesis of a particular group of spinels. Nevertheless, already at that time, I was also carrying out my first analytical activities necessary to characterize the products of my experiments.

My real adventure with analytical chemistry started at the University of Warsaw with a Ph.D. project focused on flow-injection analysis (FIA) which was, at that time, a new technique introduced in Poland by Prof. Marek Trojanowicz. My Ph.D. project dealt with the development of a flow injection system with a multi-LED detector for photometric measurements. I was quickly enchanted by the elegance of this concept that, in a way, even now still stays with me - peaks, not FIA but chromatographic ones, have been accompanying me for the rest of my career. After my Ph.D., I have had an extraordinary opportunity to be a part of the beginnings of an emerging field of analytical chemistry - speciation analysis. I started at the University of Antwerp, in the group of Prof. Freddy Adams, where I participated in method development for environmental projects dealing with the long-distance transport of organolead compounds from leaded gasoline (which was still in use at that time) and with organotin cycling in the marine environment. I continued and expanded the latter in the frame of my post-doctoral fellowship with the European Environmental Research Organization at the University of Bordeaux. At that time, in that part of France, there were still fresh memories of the problems in oyster farming in the Bay of Arcachon related to the use of antifouling paints containing tributyltin. Therefore, there was a need for analytical methodologies able to follow the release of butyltin compounds into seawater, their uptake by marine biota and incorporation into sediments. Looking back at these two post-doctoral stays I realize that they shaped my final research interests and my whole career up to now.



During PhD at the Laboratory of Flow Analysis and Chromatography at the Faculty of Chemistry, University of Warsaw, Poland (1990).

BrJAC: What has changed in the student profile, ambitions, and performance since the beginning of your career?

Dr. Szpunar: It is certain that many changes have occurred since I was a university student. The most striking one, and here I am speaking from the European perspective, is the increase in the number of students and the trivialization of certain university studies. It seems now to be a natural continuation of high school and, in some places, there is even no selection for enrollment. As a consequence, some choices are not well thought through, and many students resign during the first or second year. It is a terrible waste of resources and a source of disappointment and stress for both students and university teachers. At the same time, there is less personal contact between students and professors who have no chance to get to know each other and to interact. This situation was further aggravated by the COVID-19 crisis and on-line teaching. Another issue is a change in the very concept of higher education with universities sometimes considered as providers of services and diplomas. I see more and more business-like relationships with students paying a certain price and expecting a service in exchange. I also have an impression that today's students are much more focused on their career paths and have no time (or desire) for exploration of the broader context of their work. This situation makes me uneasy. A recent *Nature* paper (<https://doi.org/10.1038/s41586-022-05543-x>) claims that scientific papers and patents are becoming less disruptive over time which might result from "a tunnel perspective" without a general overview. And if that is lost, we will be heading towards smaller and smaller research compartments, or bubbles, isolated and not communicating with each other and thus blocking progress in each of them.

BrJAC: What are your lines of research? What work are you currently developing?

Dr. Szpunar: As I have already mentioned, during the last 30 years I have been developing an analytical methodology for species-selective studies. The concept of chemical speciation emerged gradually from the work of biologists, medical doctors and nutritionists dating back many years, certainly to the middle of the previous century. The realization that the information on total element content was insufficient resulted from the observations that the essentiality of a trace element in biology depends on the species, for example, for hemoglobin or cobalamin. In addition, the toxicity of a trace element in the environment is species-dependent, therefore there is no point in determining total tin if the toxic compound is tributyltin. Then come the metabolic pathways of metals and metalloids that can only be understood if we determine species and not the total element content as it is the case for arsenic, whose poisonous notoriety results from essentially one chemical form (arsenic(III)). During these early days, the analytical procedures were tedious, focused on single species and originally did not refer to speciation at all! In fact, the term "speciation" was mainly used in biology and not in chemistry.

A breakthrough came with the concept of coupling chromatographic separation techniques with element-selective detectors allowing clear visualization of the trace element distribution among different species in the form of multiple peaks in the chromatograms. To cut a long story short, the improvements in analytical methodologies, especially related to the introduction of highly sensitive inductively coupled plasma mass spectrometric detection, resulted in discovery of more and more element species in the studied samples. It led to the possibility of studies of previously unknown endogenous species. However, analytical chemists are faced with the problem of the identification and quantification of tens and hundreds of species for which no analytical standards exist. Indeed, with time and increase in sensitivity, the chromatograms started to show dense forests of peaks to the point that we had to employ multidimensional chromatographic schemes to improve species separation. Despite that, the chromatographic peak capacity still proved insufficient, and the paradigm had to be changed to the peak capacity in high resolution mass spectra.

My work, carried out in close collaboration with Prof. Ryszard Lobinski, addresses these challenges by taking advantage of high-resolution high accuracy molecular mass spectroscopy, mainly electrospray ionization mass spectrometry. At the Institute of Analytical and Physical Chemistry for the Environment and Materials (IPREM), which is affiliated with the National Research Center of France (CNRS) in Pau, France, our group has pioneered and developed a concept of the parallel element- and molecule-specific detection



At the 2019 Rio Symposium on Atomic Spectrometry in Mendoza, Argentina with Prof. Érico Flores (left) and Prof. Ryszard Lobinski (right).

in liquid chromatography for speciation analysis. This approach allowed us to characterize seleno-, arseno- and metal-metabolites of many complex biological systems. Our findings allow better understanding of the uptake and metabolization of metals and metalloids by microorganisms and plants in the environment and biotechnological processes aimed at the development of food and feed supplements. The recent projects concerned characterization of selenometabolites in selenium-enriched probiotic *Bifidobacterium longum* and different yeast strains, species involved in translocation of Zn and Cu in indigenous plants from post-mining areas in Peru, and iron complexes with

metallophores excreted by bacteria present in peat from the neighboring Pyrenees area. Our research resulted in the identification of molecular targets of metals in biological systems including, among others, Bi-binding proteins in *Helicobacter pylori*, tumor-related polypeptide in human epidermal keratinocytes upon exposure to Ni nanoparticles, Cd-metallothionein complexes in kidney cell lines upon exposure to CdS nanoparticles, I-containing proteins in algae, as well as selenoproteins in bacteria and plants.

We have been making constant progress towards the detection, identification and characterization of metal species in biological systems. The currently available techniques allow us to identify many metal compounds and rapidly get multispecies distribution patterns in complex matrices. But we aspire to go a step further beyond pure observation and to understand why and how metal species are synthesized. What are the mechanisms making an organism facing an excess or a deficit of metal to synthesize a particular species? Metal ions are part of a global biochemical network including genes, proteins and metabolites and their complexes appear because there is a ligand produced by an enzyme and there is gene expression of the enzyme triggered by the presence or absence of a metal. This brings us to metallomics, a field of research largely influenced, if not created, by the progress of trace metal speciation analysis. The term was originally proposed by Prof. Haraguchi from the University of Nagoya who defined “metallomics” as metal-assisted functional biochemistry and postulated it to be considered at the same level of scientific significance as genomics or proteomics. Our group has been active in the field of metallomics from the very beginning working in close collaboration with molecular biologists. Indeed, information delivered by the novel speciation analytical tools has reached the level where it is attractive for genetic and molecular biology studies aimed at elucidation of biological mechanisms involving essential, toxic, and therapeutic metals and metalloids and their compounds.

This new broad understanding of metal/metalloid-related research led me to get familiar with the basics of life sciences in order to grasp the context of interdisciplinary projects and to be able to creatively contribute to their realization.

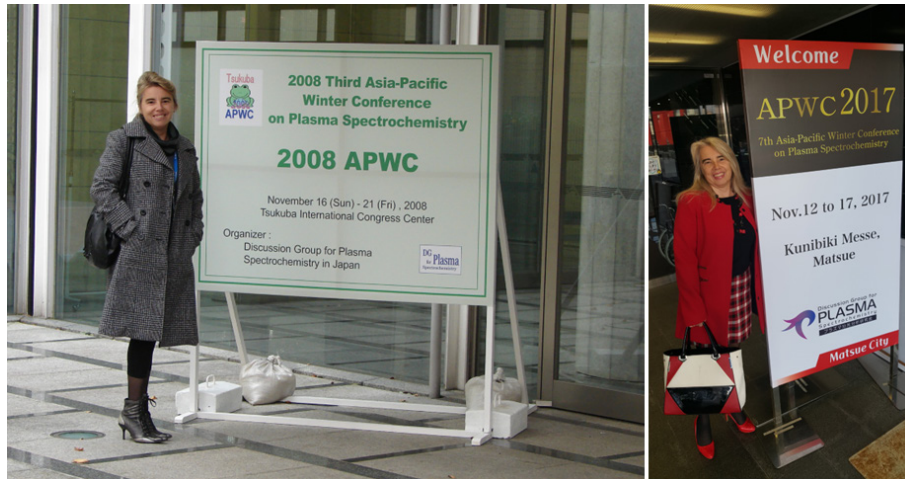
BrJAC: For you, what have been the most important achievements in the analytical research field recently? Could you briefly comment on recent advances and challenges in analytical chemistry considering your contributions?

Dr. Szpunar: From my point of view the most important are amazing developments in high-precision high-resolution mass spectrometry allowing access to the isotopic fine structure corresponding to the combination of all the isotopes constituting molecules. It opens the door to the experimental determination

of molecular formulas that can serve as a basis for the identification of unknown species. This capability, combined with multistage fragmentation of molecular ions for their structural characterization, has become an indispensable tool in modern speciation analysis and metallomics studies. At the same time, the progress in inductively coupled plasma mass spectrometry (ICP-MS) made it easier to follow elements (such as, sulfur or phosphorus) offering complementary information about the metal-containing species detected. Also, the introduction of single-particle ICP-MS helped to account for nanoparticles, another form of the chemical species present in some biological systems. Also, on this basis, studies could be developed for the metabolization of metal-containing nanoparticles with possible formation of new species.

BrJAC: There are several meetings of chemistry experts that take place around the world. What is the importance of these meetings to the development of the area?

Dr. Szpunar: I strongly believe in the importance of personal contacts. The nature of research work is very closely linked to the personal qualities of people, their intelligence, curiosity and vision and can only flourish when exposed to ideas of fellow scientists. It is especially true nowadays after the pandemic when many pre-crisis collaborations were weakened or abandoned. Also, interdisciplinary contacts are a must and are much more difficult to develop without a direct face-to-face discussion. I am a regular participant of several analytical chemistry meetings, including the Winter Plasma Spectrochemistry Conference, the Colloquium Spectroscopicum Internationale, the Instrumental Methods of Analysis conference as well as the International Metallomics Symposium and some other interdisciplinary ones related to current projects of our group. It is evident that staying in one's bubble means missing opportunities and narrowing horizons. In addition growing specialization and partitioning of research disciplines make reaching out to colleagues from other disciplines more and more challenging. New ideas are often born not only while listening to the presentations but during informal contacts during coffee breaks, dinners or even conference excursions.



At the Asia-Pacific Winter Conferences on Plasma Spectrochemistry: 2008 in Tsukuba and 2017 in Matsue, Japan.

BrJAC: Do you believe that the current graduate programs produce quality researchers in the field of analytical chemistry? Is there a need for further integration?

Dr. Szpunar: This question is a little difficult for me because I do not teach on a regular basis so - not being personally involved in the process - I do not feel comfortable criticizing. Nevertheless, I do have contact with students coming to our lab to carry out their Master internships and I supervise Ph.D. projects. What I observe is a large variation in the competencies among students coming to our laboratory. From my experience it comes from the possibility of choosing an individual path in terms of the modules studied; although attractive *per se*, it sometimes results in the lack of very basic skills and knowledge. The notion

of inclusivity, although very noble, often backfires when a student arrives at the high education level not prepared to face the challenges. Also, where Ph.D. programs are concerned, there is an enormous pressure on providing a degree within a given time frame, which might be difficult in experimental science when new concepts are tested. It sometimes leads to abandoning “high gain - high risk” ideas and choosing an already beaten path. In such situations the lesson learned by the student is not the best for his creativity and professional future.

Since the essence of analytical chemistry is the laboratory work, I believe the earliest possible integration into the experimental activities, with exposure to real life problems, is key for gaining the skills necessary for a successful career in this field. I believe such participation (with its ups and downs), the choice of a scientific method to use, the hypothesis testing followed by critical evaluation of the data and the necessity of management of time and resources is an invaluable and essential part of the training.

BrJAC: For you what is the importance of the support of funding agencies for the scientific development of the country?

Dr. Szpunar: It is evident for me that funding scientific development is an important investment in the future of any society and country. And even if it is also evident that not all funded projects can be successful, nevertheless, they offer an opportunity to explore and test new ideas and provide experience allowing researchers to face new challenges. There is a never-ending discussion about the criteria for assessment of the feasibility of proposals and a choice between “high risk-high gain” and “low risk-low gain” projects. However, it has to be remembered that asking questions for which we already know answers cannot be considered a science, so opening new horizons should be a priority. At the same time, companies should be encouraged and financially motivated to contribute to projects with more applied character thus broadening the spectrum of funding options.

BrJAC: What sort of a career could someone expect in the field of analytical chemistry? What advice would you give to a newcomer to this area?



Receiving the Award of the Committee of Analytical Chemistry of the Polish Academy of Sciences presented by Dr. Barbara Wagner, 2013.

Dr. Szpunar: Analytical chemistry is a specific field that is indispensable for and, at the same time, dependent on many other research areas. It is fascinating in a sense of its capability to describe and characterize the big and small components of the world around us as well as give information about the composition of our bodies. So, a career in analytical chemistry theoretically gives endless opportunities, including forensic and clinical analysis, environmental and food safety monitoring, as well as participation in high-profile projects ranging from space exploration to development and testing new medicines. Also, there is a place for a variety of personal and professional profiles with people preferring more regular routine work (nothing wrong with that! - we badly need high quality reliable routine data!) and others who value exploration of new paths

and developing new methods for emerging analytical problems. So, my advice would be not too original - try to imagine yourself in 5 or 10 years' time and decide what position and work profile would suit best your abilities, ambition, temperament and, the last but not least, personal plans.

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BrJAC: How would you like to be remembered?

Dr. Szpunar: Well, it is a serious, I would say multidimensional, question. From a professional perspective I hope that some of the ideas presented in papers and presentations from our group may inspire young researchers, which is already a kind of positive memory. Naturally, with time, these ideas will not be considered novel anymore and the process of forgetting will start. As to the broader, personal perspective, I do hope that at least some of my colleagues with whom I shared everyday work and some collaborators from more or less distant laboratories may remember our joint efforts with a smile.