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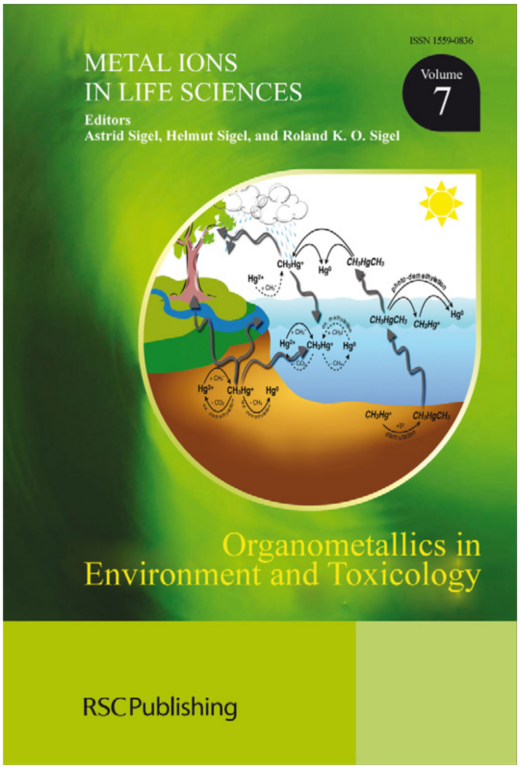
Book review

Organometallics in Environment and Toxicology, A. Sigel, H. Sigel, R.K.O. Sigel (Eds.)., Metal Ions in Life Sciences, vol. 7 RSC Publishing (2010). Hardback, Price £150.00, ISBN: 978-1-84755-177-1



The seventh volume in the Metal Ions in Life Science series, “Organometallics in Environment and Toxicology”, is related to its preceding volume, “Metal-Carbon Bonds in Enzymes and Cofactors”, which focused on living organisms (anaerobes and aerobes) hosting sophisticated catalysts such as [Ni,Fe] hydrogenases, [Ni,Fe] CO dehydrogenases, [Ni] F_{430}, or [Co] B12 enzymes. Now the focus is on organometal(loid)s in the environment and in toxicology. Again, living systems are the key players in the synthesis, transformation, remediation, and detoxification of organometallics in our biosphere. In the tradition of the series edited by the SIGELs, this volume is a comprehensive and most valuable resource for researchers working actively in the interdisciplinary field of Biological Inorganic Chemistry. The book (575 pages, over 2500 references) includes 14 chapters written by 27 authors, throughout internationally recognized experts in their special area.

In the first chapter, the reader will be introduced to roles of organometal(loid) compounds in environmental cycles (author J.S. Thayer), with specific emphasis on the biologically essential transition metals Co, Ni and Fe, followed by a discussion of organometallic compounds of toxic metals Hg, Sn and Pb, and other important elements. In summary, these organometal(loid)s, many of them methylated or permethylated substances, enhance the element mobility in lipids and aqueous phases, especially inside organisms. In chapter 2 (authors C.F. Harrington, D.S. Vidler, R.O. Jenkins) the state-of-the-art techniques for the characterization and quantification of the pertinent organometal(loid) species are critically reviewed. Knowledge of the total concentration may not give too much information about the possible environmental mobility, toxicity or biochemical activity of an organometallic compound. However, the knowledge about the actual chemical form(s) of the compound under investigation is a strict prerequisite for our understanding of the impact in many areas, such as toxicology, ecotoxicology, biogeochemistry, food safety and nutrition.

The environment in which life began may have been rather electron-rich, with H_2, CO, cyanide and metal sulfides present. Special catalysts were required to handle these compounds, thus early life-forms featured a rich biochemical role for Fe, Co, and Ni. Historically, the biologically active forms of vitamin B_{12} were the first examples of carbon-metal bonds to be discovered in biology. Clearly, that discovery opened up a new area in organometallic chemistry as discussed extensively in the preceding volume (MILS-6). Along these lines, S.W. Ragsdale and coauthors M. Dey, X. Li, and Y. Zhou (Chapter 3) continue the discussion on the importance of metal–carbon bonds in enzymatic catalysis, with emphasis on the environmentally important process of methanogenesis and its complex biochemistry. In fact, the cobalt-containing corrin-like (B_{12}) cofactor is similar to the nickel coenzyme F_{430} involved in bacterial methane formation on earth (estimated 10^9 tons per year).

Chapter 4 (authors T. Gajda, A. Jancsó) deals with the organic derivatives of tin, their synthesis, uses, environmental distribution, and their toxicity. Notably more than 800 organotins are known today, furthermore tin has a larger number of organometallic derivatives in commercial use than any other element. It is mainly the chemistry of organotins R_nSnX_m ($n = 1–4$, $m = 1–3$) in aqueous solution which is summarized in this chapter, and their general routes into the environment through complexation by naturally occurring ligands. In conclusion, organotins appear to be of major toxicological relevance, and the understanding of their aquatic chemistry is of crucial importance. When discussing organolead compounds, their impact on the environment and their health effects (Chapter 5, authors H.G. Abadin, H.R. Pohl), primarily the use of tetraethyllead and tetramethyllead as gasoline additives comes to mind. Notably, the use of alkyllead compounds has significantly declined over the past three decades thanks to the worldwide effort to eliminate leaded gasolines. Although not longer present in significant quantities in the air, still we have to cope with the degradation products of alkyllead compounds in the environment and their toxicity.

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Organoarsenicals, their distribution and transformation in the environment, their metabolism, and toxicity take center stage in Chapter 6 (authors K.J. Reimer, I. Koch, W.R. Cullen) and Chapter 7 (authors E. Dopp, A.D. Kligerman, A. Diaz-Bone). Arsenic appears to be the most significant environmental contamination of drinking water worldwide. It is ubiquitous in the biosphere and exhibits an amazingly large variety species including arsenosugars and arsenolipids, with a wide variability of toxicological effects. Many of its compounds are considered to be carcinogenic, due to the numerous structurally different compounds the carcinogenicity of arsenic is not well understood. In humans, the liver has been identified as the central site for methylation of inorganic arsenic, with the methyl donor *S*-adenosyl-methionine as the key player. Both chapters add up to an excellent introduction to a famous (thanks to Agatha Christie) element with a diverse biological chemistry. Chapter 8 (author M. Filella) is devoted to alkyl derivatives of antimony in the environment. To date, a distinct biological role could not be assigned to antimony, and it did not attract too much attention as an element of environmental concern. The existence of methylated antimony species has been reported in surface waters, sediments and biota. Furthermore, laboratory experiments have shown the ability of bacteria, yeast, and fungi to form alkylantimony compounds both under aerobic and anaerobic conditions. Thus, methylation of antimony most probably occurs in our biosphere, although in minor quantities.

Contrary to arsenic and antimony, no methylated bismuth species could be detected so far in surface waters and biota. However, as described by M. Filella in Chapter 9, volatile mono-, di-, and trimethylbismuthines have been produced by microorganisms in laboratory culture experiments. Not too surprisingly, $(CH_3)_3Bi$ was found in landfill and sewage sludge fermentation gases. In summary, bismuth is an element that appears to be relatively non-toxic to humans but still toxic for some prokaryotes. Colloidal bismuth subcitrate is successfully applied in the treatment of both gastric and duodenal ulcer disease, because of its effective action against *Helicobacter pylori*.

Chapter 10 (authors D. Wallschläger, J. Feldmann) deals with organoselenium and organotellurium compounds in the environment. Selenium, a constituent of several important redox enzymes throughout the living world, has an amazingly diverse organic chemistry. It is one of the few trace elements that may biomagnify in food chains depending on the conditions. In general, it is assumed that organioselenium species exist in ambient waters, soils, and sediments, and that they play a key role in bioaccumulation. By comparison, the diversity of organotellurium compounds is quite small. At this point, only simple methylated tellurides have been identified in the environment.

Chapters 11 (author H. Hintelmann) and 12 (authors M. Aschner, N. Ohnishchenko, S. Ceccatelli), focus on mercury, a persistent pollutant and one of the most intensively studied trace metals. Obviously, the most important mercury species in the environment is monomethylmercury, $[CH_3Hg]^+$, which is always coordinated to a soft ligand forming a 1:1 complex. Usually this compound is not released into the biosphere, but formed by biological processes, mainly via methylation of Hg^{2+} by bacteria (see Chapter 1). With regard to biomagnification its potential is remarkably high. Note that Methylmercury can be accumulated by more than seven orders of magnitude, from sub ng/L concentrations in water to over 10^6 ng/kg in piscivorous fish. These are the main concern from a human health point of view, especially because $[CH_3Hg]^+$ is a very potent neurotoxin. Its mechanisms of toxicity are reviewed in great detail, including discussions of neurodegenerative disorders such as Parkinson's and Alzheimer's disease.

The final two chapters are again of a more general nature. In Chapter 13 (written again by J.S. Thayer), the many environmental aspects of bioindication, biomonitoring, and bioremediation with all their consequences are discussed, followed by Chapter 14 (authors A.V. Hirner, A.W. Rettenmeier) reviewing methylated metal(loid) species in humans. Interestingly, arsenic, bismuth, selenium, and probably also tellurium, could be shown to be enzymatically methylated in the human body. Such methylation reactions have not yet been documented for several toxic elements, such as cadmium, germanium, indium, lead, mercury, thallium, or tin, although the latter elements have been shown to undergo biomethylation. As alkylated metal(oid)s exhibit an enhanced mobility, their transport within the human body and passage through membrane barriers will become more likely. As a consequence, human health may be affected.

In conclusion, "Organometallics in Environment and Toxicology" is a well-written book with many useful references. Not to forget the numerous informative illustrations, many of them in color. Like its preceding volume on "Metal-Carbon Bonds in Enzymes and Cofactors" it represents a valuable resource for scientists working in the wide range from organometallic chemistry, biological inorganic chemistry, environmental toxicology all the way through to physiology and medicine.

Peter M.H. Kroneck*
Fachbereich Biologie, Universität Konstanz,
Universitaetsstrasse 10, 78457 Konstanz, Germany

* Tel.: +49 7531 882103; fax: +49 7531 882966.
E-mail address: peter.kroneck@uni-konstanz.de

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