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Preface

Sulfur is the 4th most abundant element on Earth and plays a key role in many chemical and biochemical reactions. Consequently, this element plays a crucial role at many levels in our society, although its importance is not always known. For example, 50% of the drugs in current development bear at least one sulfur atom. Sulfur plays an essential role in human nutrition as it is incorporated in essential amino acids humans cannot make themselves. This becomes, for instance, a problem for rice-based nutrition, as rice contains only minor amounts of these amino acids. In addition, sulfur compounds play a key role in many industrial production processes, e.g., vulcanisation of rubber, pulping of wood and the photographic industry.

Although the biogeochemical sulfur cycle and its interaction with other cycles (C, Fe, N) are the subject of fascinating fundamental science, the increased anthropogenic activity leads to local imbalances of these natural cycles. These imbalances are highly detrimental leading to several serious environmental problems: acid rain (sulfuric acid production out of SO_x emissions); odor nuisance from polluted rivers, landfills or treatment systems; corrosion of steel and concrete; heavy metal and sulfuric acid release from oxygen-exposed mineral ores and soils (which are transported off-site in the so-called acid mine drainage). Industrial wastewaters containing sulfur compounds also contribute to the imbalances of the sulfur cycle. Examples of sulfate-rich wastewaters are those produced by industries that use sulfuric acid (e.g., food and fermentation industry) or sulfate-rich feed stocks (e.g., sea-food processing industry). Reduced sulfur compounds can also be present in wastewaters, such as sulfide (tanneries, Kraft process for wood pulping), sulfite (sulfite pulping), thiosulfate (fixing of photographs) or dithionite (pulp bleaching). Recently, considerable attention is also given to the deleterious presence of organosulfur compounds in petroleum and other fossil fuels. In addition to the inorganic sulfur species such as elemental sulfur, sulfate, sulfite, thiosulfate and sulfide, more than 200 sulfur-containing organic compounds have been identified in crude oil. These include thiols, thiophenes, substituted benzo- and dibenzothiophenes, and many considerably more complex molecules.

Sulfur cycle based biotechnologies rely on the formation of thermodynamically stable sulfur stocks, of which three types are found in nature. The bulk of the sulfur is present in sediments and rocks in the form of sulfate minerals (primarily as gypsum, $CaSO_4$), sulfide minerals (primarily as pyrite, Fe_2S) and sulfur deposits (S^0), which have been formed in various different geological periods. In fact, environmental technology also uses the same insoluble solid intermediates that accumulate in nature ($CaSO_4$, metal-sulfides and S^0) for the abatement of sulfur pollution, as these solid phases permit efficient separation from the liquid phase. It is important to note that all gaseous sulfur compounds (e.g., H_2S and volatile organic sulfur compounds such as dimethyl sulfide and mercaptans) are toxic, corrosive and odorous. Thus, production of gaseous end products is not an option for pollution abatement in the sulfur cycle. Accordingly, reactor concepts designed for the removal of carbon and nitrogen, where the production of, respectively, CO_2/CH_4 and N_2 is the common method applied for their removal, are not suitable. In the last decades, progress has been made with novel biotechnological processes that utilize sulfur cycle conversions up to a point that these processes are now successfully introduced into the market. These include the production of biogenic sulfide for heavy metal removal from heavy metal laden wastewaters and acid mine drainage as well as biological desulfurization of natural gas, flue gases, LPG, oil and rubber.

Despite its importance in environmental pollution and bioremediation, the sulfur cycle is also important from a basic scientific point of view. Despite that some sulfur-transformations occur at considerable rates chemically, the global sulfur cycle is strongly accelerated by microorganisms. Marine systems as microbial mats, continental shelves and hydrothermal vents are driven by sulfur, although many of the microorganisms in these environments have not yet been described. Sulfur conversions involve the metabolism of several different specific groups of bacteria specialized to use these sulfur compounds (e.g., sulfate reducing bacteria, colored sulfur bacteria, thiobacilli). These bacteria possess unique metabolic and eco-physiological features. This is clearly illustrated by the recent discovery of *Thiomargarita namibiensis*, the largest bacterial species known thus far with an average size of about 0.75 mm. The special features of these organisms make them useful in frontline research for the development of new analytical techniques as well as novel bioprocess applications.

This special issue illustrates the variety of exiting research done in the area of the biological sulfur cycle, including basic cutting edge fundamental research as well as challenging applied research to abate pollution by sulfur compounds or heavy metals. Part of the papers were presented at the Euro Summer School "The Sulfur Cycle in Environmental Biotechnology: Options for Sulfur and Heavy Metal Removal/Recovery" held May 12–17, 2002 in Wageningen (The Netherlands), financially supported by the Improving the Human Potential Program of the EU (IHP-1999-0060).

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