The Handbook of Environmental Chemistry

Founded by Otto Hutzinger

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Volume 61

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Electro-Fenton Process

New Trends and Scale-Up

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– Editorial Board
– Aims and Scope
– Instructions for Authors
– Sample Contribution

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Aims and Scope

Since 1980, *The Handbook of Environmental Chemistry* has provided sound and solid knowledge about environmental topics from a chemical perspective. Presenting a wide spectrum of viewpoints and approaches, the series now covers topics such as local and global changes of natural environment and climate; anthropogenic impact on the environment; water, air and soil pollution; remediation and waste characterization; environmental contaminants; biogeochemistry; geoecology; chemical reactions and processes; chemical and biological transformations as well as physical transport of chemicals in the environment; or environmental modeling. A particular focus of the series lies on methodological advances in environmental analytical chemistry.

Series Preface

With remarkable vision, Prof. Otto Hutzinger initiated *The Handbook of Environmental Chemistry* in 1980 and became the founding Editor-in-Chief. At that time, environmental chemistry was an emerging field, aiming at a complete description of the Earth's environment, encompassing the physical, chemical, biological, and geological transformations of chemical substances occurring on a local as well as a global scale. Environmental chemistry was intended to provide an account of the impact of man's activities on the natural environment by describing observed changes.

While a considerable amount of knowledge has been accumulated over the last three decades, as reflected in the more than 70 volumes of *The Handbook of Environmental Chemistry*, there are still many scientific and policy challenges ahead due to the complexity and interdisciplinary nature of the field. The series will therefore continue to provide compilations of current knowledge. Contributions are written by leading experts with practical experience in their fields. *The Handbook of Environmental Chemistry* grows with the increases in our scientific understanding, and provides a valuable source not only for scientists but also for environmental managers and decision-makers. Today, the series covers a broad range of environmental topics from a chemical perspective, including methodological advances in environmental analytical chemistry.

In recent years, there has been a growing tendency to include subject matter of societal relevance in the broad view of environmental chemistry. Topics include life cycle analysis, environmental management, sustainable development, and socio-economic, legal and even political problems, among others. While these topics are of great importance for the development and acceptance of *The Handbook of Environmental Chemistry*, the publisher and Editors-in-Chief have decided to keep the handbook essentially a source of information on "hard sciences" with a particular emphasis on chemistry, but also covering biology, geology, hydrology and engineering as applied to environmental sciences.

The volumes of the series are written at an advanced level, addressing the needs of both researchers and graduate students, as well as of people outside the field of

"pure" chemistry, including those in industry, business, government, research establishments, and public interest groups. It would be very satisfying to see these volumes used as a basis for graduate courses in environmental chemistry. With its high standards of scientific quality and clarity, *The Handbook of Environmental Chemistry* provides a solid basis from which scientists can share their knowledge on the different aspects of environmental problems, presenting a wide spectrum of viewpoints and approaches.

The Handbook of Environmental Chemistry is available both in print and online via www.springerlink.com/content/110354/. Articles are published online as soon as they have been approved for publication. Authors, Volume Editors and Editors-in-Chief are rewarded by the broad acceptance of *The Handbook of Environmental Chemistry* by the scientific community, from whom suggestions for new topics to the Editors-in-Chief are always very welcome.

Damià Barceló
Andrey G. Kostianoy
Editors-in-Chief

Preface

Even though the existence and performance appraisal of Fenton's reaction dates back to almost 150 years, the feasibility of full-scale environmental applications has become nowadays a very hot topic. Among the large variety of existing processes whose reactivity is pre-eminently determined by the metal-catalyzed transformation of a mild oxidizing reagent like H_2O_2 into the second strongest oxidant known ($^{\bullet}OH$), electro-Fenton (EF) process has become one of the most successful, especially for destroying organic pollutants. The origins of EF can be found in organic electrosynthesis in the 1970s, but soon it was adopted as a promising system in the environmental electrochemistry field. EF combines simplicity with outstanding performance in terms of degradation rate and decontamination percentage, overcoming the major drawbacks of conventional Fenton process such as significant sludge generation and need of continuous H_2O_2 addition.

The main feature of EF, that is to say, the one that allows making the difference between this and other Fenton-based processes for water decontamination and disinfection, is the electrogeneration of H_2O_2 on site from the two-electron reduction of oxygen, thus avoiding the cost and risks associated with production, mobilization, storage, and use of industrially synthesized H_2O_2. In addition, the continuous regeneration of Fe(II) catalyst from cathodic reduction of Fe(III) ensures a permanent catalytic activity and minimizes sludge management.

This book is dedicated to the EF process, embracing from its first steps to the newest trends and scale-up, in 15 chapters. Despite the lack of a strict division between the various aspects that are presented, the chapters could be considered as grouped into four different parts: the first four chapters list and describe the alternative EF setups, from conventional to the most recent ones; then, there appear three chapters on advances in cathode materials; reactor engineering and modeling are explained in the subsequent four chapters; the book concludes with four chapters that deal with applications in soil and water treatment.

In the first chapter, Profs. Sirés and Brillas make a very thorough description of EF fundamentals and reactivity, including up to 50 reactions to unravel the complexity of such systems. Then, Dr. Olvera-Vargas and coworkers give all details on

a new combined process called bio-electro-Fenton. Prof. Wang focuses on the so-called electro-peroxone technology, which combines cathodic H_2O_2 production with conventional ozonation to upgrade the latter process thanks to $^{\bullet}OH$ generation. Dr. Nidheesh and coworkers describe the fundamentals of heterogeneous EF process, which relies on the use of insoluble solid catalysts to promote the removal of organic pollutants from water with the possibility to recover the catalyst.

The three chapters devoted to cathode modification for enhancing the H_2O_2 electrogeneration are presented by Profs. A. Khataee and A. Hasanzadeh (use of carbon-based nanomaterials like carbon nanotubes, graphene, and mesoporous carbon), Dr. Le and coworkers (use of carbon felt), and Prof. Zhou and coworkers (use of modified graphite felt and composites with carbon black or graphene). These chapters include characterization of modified materials as well as performance assessment regarding pollutant destruction.

Reactor engineering and modeling is first addressed in the chapter of Profs. Scialdone and Panizza, experts in either microreactors or conventional reactors. The flow-through reactor for EF treatment is described by Prof. Zhou and coworkers, who explain the enhanced mass transport and electron transfer upon use of such configuration. Profs. Nava and Ponce de León introduce in a detailed manner the principles of reactor design and comment on the modeling of a solar photoelectro-Fenton flow plant. To sum up with this part, Profs. Álvarez Gallegos and Silva Martínez focus on the elucidation of a semiempirical chemical model to predict the time course of organic pollutants in EF treatments.

The last chapters contain different applications of EF and related processes. First, Prof. Brillas shows the great performance of solar photoelectro-Fenton process for wastewater treatment. Then, Drs. Plakas and Karabelas summarize the state of the art of pilot, demonstration, and full-scale EF systems, including a patent survey. Dr. Lin and coworkers show the results of EF treatment of artificial sweeteners (aspartame, sucralose, saccharin, and acesulfame) in aqueous medium. And finally, Dr. Mousset and coworkers discuss the feasibility of soil remediation by EF.

We believe that this book, which has been written by world leading experts, constitutes a timely milestone for scientists and engineers alike. It constitutes a platform for addressing the most challenging issues and future prospects of EF process. From the excellent results that have been obtained so far, we aim to foster the gradual scale-up and implementation of this electrochemical technology in the public and private sector. We would like to acknowledge very warmly all the authors, who are kindly involved in this project and committed to clearly explain the pros and cons of EF technology. We are also thankful to Springer for their support in publishing this book.

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Contents