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Emerging Organic Contaminants and Human Health

Springer

Emerging Organic Contaminants and Human Health

Volume Editor: Damià Barceló

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The Handbook of Environmental Chemistry
ISSN 1867-979X ISSN 1616-864X (electronic)
ISBN 978-3-642-28131-0 ISBN 978-3-642-28132-7 (eBook)
DOI 10.1007/978-3-642-28132-7
Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2012935241

The Handbook of Environmental Chemistry

Founded by Otto Hutzinger

Editors-in-Chief: Damià Barceló • Andrey G. Kostianoy

Volume 20

The Handbook of Environmental Chemistry

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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

Volume Preface

Global changes, including socio-demographic and environmental issues, are challenges to our society. Drivers of global change are climate change, population growth, urbanization, industrialization, and rising income, living standards, and water and energy demand. These forces will be confounded by slowing productivity growth, falling investment in irrigation and agriculture worldwide, loss of biodiversity, risk to public health, and water scarcity, among other issues. Future population growth and water scarcity pose significant risks to global food security, as it has been already pointed out by Professor John Beddington, UK Government Chief Scientist, in March 2009, by the so-called "Perfect Storm" of problems by 2030 [1]. This perfect storm involves food shortages, scarce water, and insufficient energy resources that threaten to unleash public unrest, cross-border conflicts, and mass migration as people flee from the worst affected regions.

It is nevertheless remarkable that water, sanitation, and health nexus were among the earliest issues being reported. The connection between human health and well-being and access to sufficient drinking water has long been recognized. Public health and epidemiology started on the concept of water-borne diseases, and the nature of human exposure to bacteria in polluted waters has driven the mandate for sanitation and hygiene, still important throughout the world today. Already in 1514 anonymous maps displayed drainage to improve public health in Italy. Through the London epidemics of 1849 and 1854, Snow [2] verified his hypothesis that contaminated water was the critical variable in cholera transmission, when he plotted cases and the area of water distribution.

But we know that human exposure to different contaminants takes place also via food, air, and dust. The influence of diet on human concentration of persistent organic pollutants or the links between air pollution and adverse health effects has been recognized.

A lot of information already exists on regulated contaminants and human health, but there is less information on the influence of the so-called emerging contaminants and nanomaterials. Due to the fact that most of the emerging organic contaminants are not regulated, a few studies are available in relation to human health issues. For this reason I think that this book is timely due to increased interest in the last years to bridge human health with environmental and food contamination. The establishment of relationships between human health and levels some of these emerging contaminants in body fluids is taking place at global scale,

from USA, China, and EU countries. Links between antibiotic resistance due to the use of large amounts of antibiotics for human and veterinary purposes, or the direct relationship between levels of drinking water disinfection by products with bladder cancer, asthma, genotoxicity, and cytotoxicity were established. One of the most recent issues of concern is the use of nanomaterials in food industry via food packaging and their way that these nanomaterials migrate to the food. The European Food Safety Authority (EFSA) has already published a report on that emerging issue.

The book contains 14 chapters that cover several chemical groups of emerging organic contaminants, several of them are persistent, bioaccumulative, and toxic (PBT) while others are associated with other effects such as endocrine disruption, antibiotic resistance, and bioaccumulation in biota. One of the groups with more chapters on this book are the pharmaceuticals with emphasis on antibiotics and on all the problems associated with the increased pharmaceutical products used in hospitals as well as the issue of ecopharmacovigilance that was introduced in 2008. Other emerging contaminants reported are brominated flame retardants, polar pesticides, phthalates, phosphate esters, perfluorinated compounds, personal care products, musks, and illicit drugs among others. The various chapters describe levels in environmental, food, and health matrices with the exception of the two chapters of the book that dealt with toxicological and ecotoxicological issues of the emerging contaminants.

This book is intended for a broad audience, from analytical chemists, environmental chemists and engineers, toxicologists, ecotoxicologists, and epidemiologists working already in this field as well as newcomers including students in their first years of their Ph.D. who want to learn more about this issue. Finally, I would like to thank all the authors for their time and efforts in preparing the corresponding chapters that make this book unique in this HEC series.

Barcelona, Spain Damià Barceló

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Emerging Organic Contaminants and Nanomaterials in Food

Marinella Farré and Damià Barceló

Abstract Governments all over the world are intensifying their efforts to improve food safety. These efforts come as a response to an increasing number of food safety problems and rising consumer concerns. In addition, the variety of toxicant residues in food is continuously increasing as a consequence of industry development, new agricultural practices, environmental pollution, and climate change. This paper reviews the major groups of emerging contaminants in food, as well as, the levels of concentrations reported and the analytical approaches presented for their detection with special emphasis on more fast and cost-efficient methods of detection.

The four main groups of emerging food contaminants that are discussed here are:

1. Industrial organic pollutants: Perfluorinated compounds (PFCs), polybrominated diphenylethers (PBDEs), new pesticides, and nanomaterials.
2. Pharmaceutical residues: Antibiotics and coccidiostats
3. Biotoxins: Emerging groups of marine biotoxins

Keywords Biotoxins, Coccidiostats, Food contaminants, LC-MS/MS, Nanomaterials antibiotics, Perfluorinated compounds, Pesticides, Polybrominated diphenylethers

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D. Barceló (ed.), *Emerging Organic Contaminants and Human Health*,
Hdb Env Chem (2012) 20: 1–46, DOI 10.1007/698_2011_137,

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1 Introduction

Contaminants are substances that have not been intentionally added to food. These substances may be present in food as a result of the various stages of its production, packaging, transport, or holding. They also might result from environmental contamination. Since contamination generally has a negative impact on the quality of food and may imply a risk to human health, the EU has taken measures to minimize contaminants in foodstuffs.

There are many thousands of chemical substances in food; most of them being of natural origin. A number, however, are man-made and arise from the use of agrochemicals, or due to pollution of water, soil and air, or occur during food preparation/processing. In addition, food may contain biological contaminants. A range of additives may also be added for a variety of purposes (e.g., to enhance the flavor, color, improve stability).

Therefore, while consumers expect the food that they eat to be safe, as a consequence of industrial development, pollution, and climate change, the variety of food contaminants are increased. Currently, one of the great challenges in food safety is controlling the risks associated with mixtures of contaminants, which continuously are changing.

Among the most prominent groups of emerging food contaminants can be considered industrial origin contaminants as perfluorinated compounds (PFCs), polybrominated biphenyls (PBBs), the new generation of pesticides, nanomaterials, and emerging groups of marine biotoxins (such as palytoxins and spirolides). Many of them are of particular concern because they can cause severe damages in human health; for example, some of them are suspected to be cancer promoters. Other selected compounds have been related to endocrine disruptor effects or can be accumulated and biomagnified through the food chain.

In this review, we have been selected the most relevant groups of emerging food contaminants. We also included some groups of pharmaceuticals of special concern such as antibiotics which can create bacterial resistances and which are illegally used as growth promoters. The main sources of the selected groups of contaminants will be discussed together with their toxicological data and concentrations reported during the last few years. The strategies for their analysis including sample preparation, separation, and detection will be presented.

2 Sources of Food Contamination, Properties and Toxicological Properties

2.1 Industrial Origin Compounds

Since the industrial revolution in the nineteenth century, the knowledge on chemistry was developed rapidly, together with several industries. Currently, under the REACH legislation more than 100,000 compounds have been pre-registered for use within the European Union. Chemicals are present in all kinds of industrial applications and consumer products. However, some of these compounds or their degradation products can cause damage to the environment and human health.

Food safety, have to face the possible contamination produced during the whole process, including those from environmental contamination or used directly related to the food production (pesticides, veterinary drugs, contamination associated with cooking, processing, packaging, and conservation, among others).

In addition, some compounds are classified as persistent organic pollutants (POPs), because of their resistance to degradation and can be bioaccumulated, show long-range transportation, and are toxic. Most POPs are lipophilic and their uptake rates in organisms are higher than the rate of depuration. This results in an accumulation in aquatic, terrestrial organisms and in humans. Further transfer-up in the food chain can lead to elevated levels in top predators (biomagnification). Their toxic properties can cause serious health damages such as the development of certain types of cancer, metabolic dysfunctions, and endocrine disruption. Initially, 12 chlorinated compounds were classified as POPs and following the ratification of the Stockholm Convention, parties took action in order to reduce the emissions of the 12 POPs. The production and use of POPs was substantially decreased (such as p,p'-DDT), and almost completely stopped for some compounds in most countries. However, some groups of compounds largely used and produced during the last decades meet the definition of POP. Examples of these new POPs are perfluorinated compounds (PFCs), brominated flame retardants (BFRs), such as polybrominated diphenyl ethers (PBDEs), and hexabromocyclododecane (HBCD). The restriction and replacement of some of these compounds should be carefully evaluated. Also, the possible alternative compounds that have to be taken into account include

effectiveness, persistence, bioacculative effects, toxicological properties, economic feasibility of their production, and human and environmental risk assessment.

On the other hand, during recent years, nanotechnology has emerged, presenting a great variety of new materials, allowing new applications for all industrial sectors including food industry. Nevertheless, while nanotechnology is successfully introduced in the industry, their possible risk to the environment and human health is not well understood and assessed. In addition, food industry has developed a variety of applications based on engineered NPs and nanomaterials, such as high loadings of vitamins and health benefits active in food, new methods for flavor stabilization, as well as, natural food-coloring dispersions can be developed. But NPs and NMs also appear as a new group of possible food contaminants, whereas their detection and characterization in food is poorly developed, and the potential risks of the application or associated contamination in food need to be understood.

In this section, emerging food contaminants with industrial origin, including perfluorinated compounds, polybrominated compounds, new pesticides, and nanomaterials will be discussed.

2.1.1 Perfluorinated Compounds

PFCs comprise a large group of compounds characterized by a fully fluorinated hydrophobic linear carbon chain attached to one or more hydrophilic head. PFCs repel both water and oil, and are therefore ideal chemicals for surface treatments. These compounds have been used for many industrial applications including stain repellents (such as Teflon), textile, paints, waxes, polishes, electronics, adhesives, and food packaging [1].

Usage and disposal of PFCs has led to the widespread distribution of these chemicals in the environment. Furthermore, PFOS and PFOA, as well as other perfluorocarboxylic acids (PFCAs) are stable degradation products and/or metabolites of neutral PFCs like fluorotelomers alcohols (PFTOHs), perfluorinated sulfonamides (PFASAs), and perfluorinated sulfonamide ethanols (PFASEs) [2]. PFCs are bioaccumulative attached to proteins and, these compounds have been detected in different water matrices [3, 4], wildlife [5, 6], fish [6], and humans [7]. In addition, PFCs are biomagnified in the food chains [5, 8], leading to increased levels in animal-derived foods. Main sources of human exposure to PFCs have been identified through: drinking water, food, and dust inhalation. Bioaccumulation in fish has been shown to be one of the main influences of PFCs in dietary exposure. Food preparation is another relevant source of food contamination [9], but preliminary data on the influence of domestic cookware on levels of PFCs in the preparation of food indicated no elevated levels for a limited number of experiments [10]. Packaging may also introduce PFCs used in greaseproof packaging for fast foods and special packaging. In these situations, PFCs enter into food via migration from the food package [9].