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Personal Care Products in the Aquatic Environment

Springer

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Volume Editors: M. Silvia Díaz-Cruz · Damià Barceló

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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

Nowadays major sources of water pollution are agricultural runoff and domestic and industrial effluent discharges. Organic pollutants present can accumulate in rivers and other water bodies and affect water quality and species survival. The active ingredients used in personal care products are increasingly detected in the environment and consist of a large group of chemicals with a wide range of physicochemical properties, which make them to be present in solution, adsorbed onto sediments and accumulated in biota. These substances are used in large quantities in everyday life, being added in cosmetics and personal hygiene products, such as deodorant, after shave, shampoo, perfume and makeup.

This book on *Personal Care Products in the Aquatic Environment* contains comprehensive information on the fate and removal strategies of the various ingredients used as personal care products and the aquatic environment as well as their impact on human health. Most of the published work so far deals with the stability of the commercial products and issues related to skin penetration. However, in the recent years, the general interests have shifted to know the risk of this large and diverse chemical group of anthropogenic contaminants in environment and humans. They can be considered part of the so-called emerging contaminants that are present worldwide in the aquatic environment, from groundwater to marine mussels. This book presents the latest developments as regards their determination, spatial distribution, degradation and risk categorization in the aquatic environment. This will be of great help to the reader to make a holistic picture of the current environmental problems connected with the widespread use of personal care products.

The book is structured in 14 chapters written by well-recognized experts in this field. The various chapters cover occurrence in water, solid samples and biota, advanced chemical analytical methods, non-conventional degradation technologies, (eco)toxicity and environmental and human risk assessment. The first chapter of the book is devoted to a general introduction to personal care products. It covers the key aspects of the diverse group of substances included in this category of chemicals (UV filters, preservatives, fragrances, etc.), which may be of especial

interest for newcomers and first-year Ph.D. students. The information provided includes physicochemical characterization, regulatory frameworks and health effects on biota and humans. In the final chapter, we discuss the major scientific achievements and future research trends. Knowledge gaps are identified too as regards the environmental and human issues associated to the daily use of personal care products.

We expect that *Personal Care Products in the Aquatic Environment* will become a useful book. The book is multidisciplinary, so it will attract experts from various fields of expertise like analytical and environmental chemistry, toxicology and environmental engineering. Since the book also covers not only continental but also marine waters, it should be of interest to the researchers working in marine pollution and related activities like aquaculture.

Finally, we would like to express our gratitude to all the contributing authors of this book for their willingness, effort and time devoted to the preparation of their respective piece of research.

Barcelona, Spain
March 2015

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Damià Barceló

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Introduction: Personal Care Products in the Aquatic Environment

Daniel Molins-Delgado, M. Silvia Díaz-Cruz, and Damià Barceló

Abstract This chapter presents an overview of the main aspects relating to the occurrence and impact of ingredients in personal care products to the aquatic environment: methodologies of analysis, prevalence data, elimination processes, threats to the aquatic ecosystem, effects on biota and legislation with a special focus in European regulation. Water is a valuable resource for the environment as well as for human activities. Although it covers most of the Earth's surface, the amount of usable water is finite. Since ancient times until now, the use of water in human activities has been rapidly increasing along with the increase of the population, producing a continuous release of pollutants into the aquatic environment. Personal care products are a widely used group of substances that have been raising concerns during the last decades due to its continuous release into the environment and its proven effects (mostly on in vitro and in vivo assays) as a threat to all kinds of living organisms. Recent studies suggest that its continuous application on the skin or the intake of contaminated food may cause some concerning hazardous effects in human beings. In order to ensure the protection of this key ecosystem, a series of worldwide initiatives have been taking place during the last two decades, impelling monitoring programmes and governmental regulations worldwide. The common grounds of the European Union establish a series of regulations, such as the Water Framework Directive or the Regulation on Cosmetic Products, to protect both the

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environment and the consumer with revisable lists of regulated hazardous compounds.

Keywords Aquatic environment, Environmental legislation, Health risk, Personal care products, Pollution sources

Contents

List of Abbreviations

4MBC	4-methylbenzylidiene camphor
AHTN	Tonalide
BP3	Benzophenone 3
BP4	Benzophenone 4
DEET	*N*,*N*-diethyl-meta-toluamide
EHMC	Ethylhexyl methoxycinnamate
EMEA	European medicine evaluation agency
EPA	Environmental protection agency
HHCB	Galaxolide
INCI	International nomenclature of cosmetic ingredients
Kow	Octanol-water partition coefficient
NP	Nonylphenol
NPEs	Nonylphenol ethoxylates
OC	Octocrylene
OTNE	Ethanone
PCPs	Personal care products

PVC	Polyvinyl chloride
REACH	Registration, evaluation, authorisation and restrictions of chemicals
UV234	2-(2*H*-benzotriazol-2-yl)-4,6-bis(1-methyl-1-phenylethyl)phenol
UV326	2-*tert*-buthyl-6-(5-chloro-2*H*-benzotriazol-2-yl)-4-methylphenol
UVP	2-(2*H*-benzotriazol-2-yl)-*p*-cresol
WFD	Water framework directive
WWF	World water forum
WWTPs	Wastewater treatment plant

1 Introduction

The aquatic environment as a system and resource. The quality of air, soil and water is of immediate concern because we interact with these natural resources in a daily basis, either personal, agricultural or industrial uses. Water is essential to sustain life, and it is a critical resource on which all social and economic activities, as well as the ecosystem functions, depend. Through history, the relation between human civilisation and water has been very tight: ancient Mesopotamia grew around the Tigris and Euphrates basins, ancient Egypt depended on the Nile, the Romans built an extensive network of aqueducts in order to supply enough water to their cities and commerce has been heavily carried out through navigable rivers, channels and seas. Mankind not only requires water for drinking purposes or for transportations of goods but for recreational activities, production of energy, agricultural purposes and to keep industrial activities going. Managing well this resource is critical and requires appropriate governance arrangements in order to protect it and to ensure the viability of both, the economic welfare of human activities and the sustainability of all the water-supported ecosystems, as water is not a commercial good, but a common heritage that we must protect, defend and acknowledge [1].

Water covers more than 70% of the Earth's surface. In land masses it appears under the form of rivers, streams, lakes and wetlands, while close to the continents, it takes the form of a few hundred deep shallow seas, estuaries, lagoons and bays, and the form of deep oceans when away from continental land masses. As life depends on water to survive, water bodies and water availability constitute the central factor of all habitats. If we are to consider the habitable places on Earth and the whole volume of water, it comprises nearly 99% of the Earth's habitat, being most of the vast water columns of the marine environment unobserved and mostly unknown to human beings.

There is now much concern about the extent of human actions, their capabilities to accelerate a climate change and what could be their possible outcomes. As climates on Earth are phenomena in constant change, only the magnitude of the rate at which it changes varies with time. For instance, temperature is the easiest and familiar magnitude to monitor. While land and air temperatures can vary dramatically, sea surface temperature changes are more subtle due to the high volume and high latent heat of water, conferring water bodies a great buffering

effect. When global temperatures rise, the melting of ice from the poles and the thermal expansion make the sea level to rise, producing other environmental changes. For instance, alterations on oceanic water bodies can induce important changes in climate; a weakening of the Gulf current could potentially change climate conditions and rainfall patterns.

Human population is mostly densely concentrated around water sources, particularly around rivers, mouths of estuaries and sheltered bays, being the focus of intensive human activities. Human activities are able to modify the aquatic environment through removal of biomass and habitats and via the addition of contaminants. Freshwater resources and population densities are unevenly distributed worldwide. As a result, demands already exceed supplies in regions with more than 40% of the world's population [2]. And 70% of the world's freshwater is currently used for irrigation, accounting for more than 95% of the developed water supply [3]. Sewage, agriculture and industrial pollution disrupt heavily the aquatic environment, and coming to understand the ecological responses of aquatic organisms is required in order to protect such an important source for life.

2 Anthropogenic Contamination as the Main Threat to the Aquatic Environment

The dawn of industrialisation and the quick growth of urbanisation brought a change into the social paradigm, transforming a predominantly rural planet into an urban one [4], bringing with it an increase on industrial and municipal waste in both garbage and sewage waste [5]. With it, new chemical compounds have been developed in order to improve our quality of life, increasing the productivity of activities of farms, ranches and forestry [5–7]. The quality of the aquatic environment depends deeply on both natural processes and anthropogenic activities [8]. Problems like eutrophication of the marine environment, anoxia of water bodies, loss of biodiversity, bioabsorption of pollutants and bioaccumulation processes in aquatic organisms have been reported worldwide [9, 10]. Also, the extreme changes in the weather due to climate change processes could be able to magnify them.

When talking about sources of contamination, we must define point source and nonpoint source of pollution. Point-source contaminants originate from a discrete source of contamination whose inputs into the aquatic environment can be defined through measurements of chemical residues in water, sediment or biota and/or because of a series of other factors like varying incidences of morbidity or mortality [11]. Examples of point source are municipal sewage treatment plants, industrial effluents, resource extractions and land disposal sites. Freshwater pollution has as a main source municipal wastewaters [12]. A huge volume of wastewater has been increasing along with urbanisation and economic development [13, 14] and those wastewaters are expected to grow [3]. There is a constant generation of new