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Global Risk-Based Management of Chemical Additives I

Production, Usage and Environmental Occurrence

Springer

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- Aims and Scope
- Instructions for Authors
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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; geo-ecology; 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

This first volume of the RISKCYCLE book analyzes the chemical additives used in the production of important industrial sectors. Additives are substances that are used to improve the characteristics of the final product.

In the first part, a review of the additives used in the sectors of textiles, electronics, lubricants, plastics, paper and leather is carried out with an emphasis on the function of each compound inside the product. For example, flame retardants reduce the potential ignition of the products; others are water repellent or biocides. These additives due to their chemical structure may have a potential impact on the environment or human health when released from the product.

The potential effects of the mainly used additives are presented in this volume in detail together with data on the world production and trade of these compounds. The aim of the RISKCYCLE project is to assess the risk of chemical additives at global scale, and it is therefore essential to know more about the world distribution of these compounds and their potential impact.

In the second part, a detailed perspective of the chemicals used in the aforementioned sectors in different countries is presented in case studies. One very interesting case concerning the recycling of paper in Vietnam is thoroughly analyzed. The emissions of additives from plastics in Sweden give a new insight on the subject, and the recycling of electronic waste in Brazil is also a case to highlight. These different case studies show the magnitude of the trade of these chemicals all over the world and their potential impact on human health and the environment if they are not correctly treated.

We hope that this book is of interest for the scientific community and will help to increase knowledge and awareness on issues raised by the different chemical additives used in major industrial sectors.

Finally, we would like to thank all the authors who have contributed to this book, for their effort in gathering the information and elaborating the different chapters.

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Contents

Introduction

B. Bilitewski, R.M. Darbra, and D. Barceló

Abstract Many potential hazardous compounds are traded worldwide as chemicals or incorporated as additives in consumer and industrial products. Their release to the environment has been a concern of the European Commission, UNO, WHO and OECD. The discussion of the assessment and management of chemicals and products led to the creation of the OECD programme Globally Harmonised System of Classification and Labelling of Chemicals (GHS). The World Summit encouraged countries to implement GHS with a view of having the System operating by 2008. The need to form GHS on a global scale is part of the EU policy. GHS aims to have the same criteria worldwide to classify and harmonise the responsible trade and handling of chemicals and products and at the same time protect human health and the environment. The EU will ensure transition from the current EU Classification and Labelling (C + L) system to the implementation of GHS, which harmonises with REACH registration. However, a complete picture on the global state of implementation is not available. With the growing level of worldwide trade, we however face unsafe consumer products on the market. These examples show that on a global perspective the trade of chemicals and products in a circular economy is not acceptable without globally agreed assessment methods and harmonised C + L (GHS).

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The overall objective of the Coordinating Action RISKCYCLE is to define together with international, European and national experts from different programmes future needs of R + D contributions for innovations in the field of risk-based management of chemicals and products in a global perspective using alternative testing strategies to minimise animal tests.

Keywords Chemicals, Circular economy, Globally Harmonised System, Risk assessment

The global trade of chemicals and products containing chemical additives such as paint, cosmetics, household cleaners, paper and cardboard, plastic toys, textiles, electronic appliances, petrol and lubricants has resulted in a substantial release of harmful substances to the environment with risk to man and nature on a worldwide scale.

The discussion of the assessment and management of chemicals and products at the *1992 Earth Summit* in Rio de Janeiro led to the creation of the OECD programme *Globally Harmonised System of Classification and Labelling of Chemicals (GHS)*. The *World Summit on Sustainable Development in Johannesburg 2002* encouraged countries to implement the GHS (adopted by UN ECOSOC in July 2003) as soon as possible, with a view of having the system operating by 2008.

In spite of some common efforts to harmonise the safety assessment of chemicals and products, a new problem with Recovered Material (as illustrated in Fig. 1) additionally appeared. The figure shows a simplified material flow in a circular economy at global scale with its risks for health and the environment due to the worldwide trade of chemicals and products. Circular Economy is a concept that is transforming traditional patterns of economic growth and production. The conventional perception of economic systems is that they are linear. This linear system is converted to a circular system when the relationship between resource use and waste residuals is taken into consideration.

Although the practices of circular economy have been present throughout history, the modern concept of circular economy (now under discussion in Asia and very seriously in China) was only introduced in Germany in 1998. The new threat comes from closing the loop in a global scale. Plastic, paper and cardboard, lubricants and other products undergo a recycling process and make their ways into a recovered material with unpredictable and not foreseen health and safety problems. In this way, unsafe consumer and industrial products get onto the global market. Latest reports in the news on tooth paste, toys and drinking cups from Asia releasing hazardous components prove this new problem.

Viet Nam News December 22, 2008 wrote that more than 75% of the country's empty plastic containers carrying all kinds of chemicals are recycled and sold back to the market to produce new plastic products of different type. Bangkok Post on February 8, 2009 noted that the use of substandard fertilisers and agricultural chemicals of unknown origin has badly affected rubber production in the region.

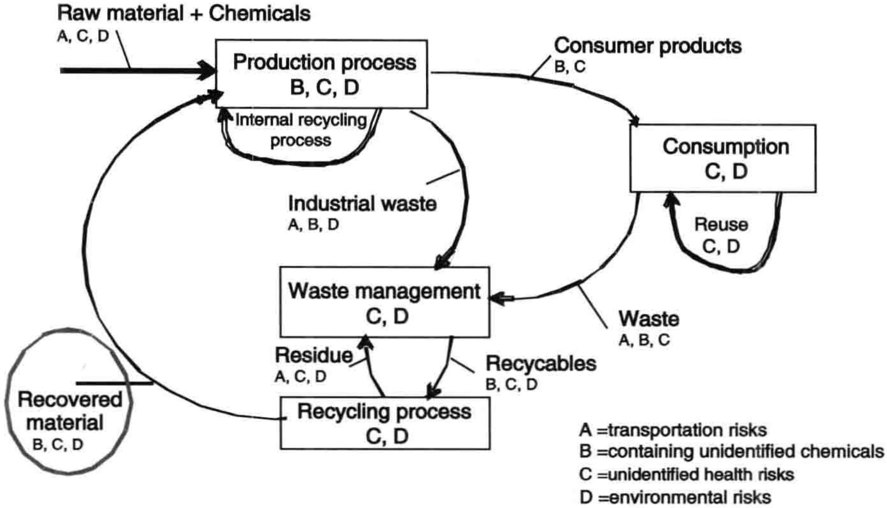

Fig. 1 Simplified material flow of a circular economy in a global scale with health and environmental risks

One compound with estrogenic activity that has been studied extensively as an intermediate in the production of polycarbonate and epoxy resin is Bisphenol A (BPA). The migration of BPA from polycarbonate flask used for baby food is enhanced when sterilisation of flask is carried out at temperatures over 80°C [1]. A recent study carried out in Germany demonstrated that estrogenic activity was detected as a result of migration of endocrine disruptors form bottled mineral water in plastic containers made of polyethylene terephthalate (PET). In contrast to polycarbonate, PET should be free form BPA. Different authors detected several phthalates in PET plastic bottles. So, it is most probably that a migration of DEHP (Di(2-ethylhexyl) phthalate) (see Table 1) occurred from PET to the bottled mineral water and afterwards the estrogenic activity was detected [2].

Waste electrical and electronic equipment, also known as e-waste, refers to the end-of-life products encompassing consumer electronics, information communication and household devices. Many of them have a short lifetime like computers, television, printers and cell phones. Therefore, e-waste is generated in large quantities with an annual volume about 20–50 million tonnes worldwide with an estimated increase of 3–5% per year [3]. Toxic substances present in e-waste are indicated in the enclosed table (Table 1). Among them, it can be found heavy metals such as lead, mercury and cadmium and persistent organ halogen compounds such as polychlorinated biphenyls (PCBs) and brominated flame retardants (BFRs). Uncontrolled e-waste recycling has become a topic of serious concern in recent years. It is estimated that up to 80% of e-waste from industrialised countries is exported to Asian developing countries, such as Vietnam for recycling and

Table 1 List of the main chemicals present in the different industrial products that will be studied in the following chapters of this book

Industrial sector	Chemical	Synonym/Substance/Acronym	CAS No.
Lubricants	Perfluoro octane sulfonate	PFOS	2795-39-3
	Perfluoro octanoic acid	PFOA	335-67-1
	Nonylphenoxy acetic acid	NPAA	3115-49-9
Textiles	Hexabromocyclododecane	HBCDD	25637-99-4
	5-Chloro-2-(2,4-dichloro-phenoxy)-phenol	Triclosan	3380-34-5
Plastics	Di(2-ethylhexyl) phthalate	DEHP	117-81-7
	Lead	Pb(II)	–
	Tri-*n*-butyltin hydride	Tributylstannane	688-73-3
Electronics	Tetrabromodiphenyl ethers	2,2',4,4'-Tetrabromodiphenyl ether (BDE 47)	5436-43-1
	Pentabromodiphenyl ethers	2,2',4,4',5-Pentabromodiphenyl ether (BDE 99)	60348-60-9
		2,2',4,4',6-Pentabromodiphenyl ether (BDE 100)	189084-64-8
	Decabromodiphenyl ether	BDE 209	1163-19-5
	Lead	Pb(II)	–
	Triphenyl phosphate	TPP	115-86-6
	Mercury	Hg(II)	–
Leather	Pentachlorophenol	PCP	87-86-5
	(Benzothiazol-2-ylthio) methyl thiocyanate	TCMTB	21564-17-0
Paper	Bisphenol A	4,4'-Isopropylidenediphenol (BPA)	80-05-7
	Dibutyl phthalate	DBP	84-74-2
	Isothiazolinones	5-Chloro-2-methyl-isothiazolin-3-one (CMI)	26172-55-4
		2-Methyl-2-isothiazolin-3-one (MI)	2682-20-4

exploiting the inexpensive labour costs and weak enforcement of environmental laws.

The paper chain is a very good example for successful recycling in Europe. However, if a deeper analysis is made, the recycling of paper and cardboard, especially for graphical paper, can introduce chemicals (from the original paper) into recovered material with unpredictable and not foreseen health and safety problems. This is the case for the thermal paper, used in cash machines and as copy paper. It has a colour developing layer with the chemical BPA. BPA is introduced into the paper cycle through the recovery of used thermal paper. BPA is found in the wastewater and detected in the next paper product. Toilet paper has a high concentration of BPA, which can be found in the wastewater after use. Printing ink used in newspaper is contaminating the cardboard for packaging and entering into the packed food exceeding the threshold values for Polycyclic Aromatics in the food by up to more than ten times [4]. All these examples show that in a circular economy the trade in a global dimension is not acceptable without a globally agreed risk assessment for existing and newly developed chemicals and products without using additional test animals.

Within this situation, the overall objective of the introduced co-ordination action RISKCYCLE aims to establish and co-ordinate a global network of European and international experts and stakeholders from different programmes and countries of the EU, USA, Japan, China, India, Brazil, Vietnam etc. to explore the synergies of the research carried out within different programmes and countries, and to facilitate the communication among researchers, institutions and industries and make the information about the risks of hazardous chemicals and additives in products and the risk reduction measures for substances widely available. As a result of this, RISKCYCLE has to define together future needs of R + D contributions for innovations in the field of risk-based management of chemicals and products of a circular economy in a global perspective making use of alternative strategies to animals test.

When addressing how this objective will be achieved, it is relevant to consider what information on present activities in this area is available and what is still unknown.

The key pieces of information that will be required and collected are:

- Where are the critical points throughout the product's life cycle for the release of chemical substances?
- How potent is the material set free? Has an evaluation and control of the risk of the substances taken place?
- Has a development of strategies for limiting the risks of these substances been done? If yes, for which substances?
- Do the effects caused by the chemicals have a global or only local meaning?
- Is the release of specific substances in the circular economy an actual risk or a perceived risk?
- Is the development of new "3R" methods (based on the principles of Refinement, Reduction and Replacement) as a modern alternative approach to the use of animals in safety assessment on a global scale, known and supported by regulators?

The specific objectives of RISKCYCLE are:

- To exploit complementary elements needed with regard to the research objectives, methodologies and data of ongoing as well as recently completed EU and international projects.
- To specify demands for tools for ecological design of consumer products, production, use and reuse of products and waste recycled to secondary material and products. Methods such as LCA (Life Cycle Assessment), risk assessment and risk reduction strategies, environmental impact analysis, material flow analysis and economics-related tools are considered to achieve socio-eco-efficient solutions.
- To create a powerful platform enabling discussion among all stakeholders on different topics: usage, risks and chemical properties of consumer products; labelling; fate of certain chemicals in products traded, used and recycled in a

global scale. The identification of problems and solutions is also an interesting aim of this platform.
- To contribute to the UN Globally Harmonised System (GHS) for chemical substances and mixtures.
- To start with a conceptual development of a global strategy for a risk-based management of chemicals and additives in recycling and trade products.
- To identify alternative testing strategies and methods to avoid the enlargement and the outsource of animal tests to East and Southeast Asia.
- To identify knowledge and research gaps for future research activities.
- To consider the most effective way of ensuring continuing progress in this field involving EU and other partners at global scale including also international organisations.

The RISKCYCLE network closely collaborates with related projects, EU and international bodies and authorities to communicate and agree on standards and to avoid duplication and redundant work.

Chemicals and additives in products being produced and marketed globally is making essential an international harmonised assessment and management. The European Commission has a vital role in stimulating global awareness throughout all sectors and in encouraging harmonisation of a system of classification and labelling (GHS) of chemicals and products. Especially recycling products with an unknown origin must be carefully considered and evaluated.

Being aware of the fact that humans and the environment are subject to the risk of chemical impacts on a day-to-day basis, management of chemicals including reduction of risks has led to the rise of several policy instruments such as different directives as well as to co-operations both at the global and European levels.

The *inter-Organization Programme for the Sound Management of Chemicals (IOMC)* was established in 1995 by UNEP, ILO, FAO, UNIDO, UNITAR and the OECD (the participating organisations) following recommendations made by the 1992 UN conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participation Organisations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment. It is clear that the contamination caused by the recycling activities, for instance e-waste should be mitigated to reduce human exposure to BFR and other toxic chemicals reported in Table 1. During e-waste recycling activities, dust ingestion by the children working at the e-waste sites should be carefully considered and investigated in the next coming years as a pathway of exposure.

At the level of the European Community, the need to protect the Community's environment and to create common standards to protect consumers in order to ensure the free circulation of goods among the Member States has been recognised leading to *REACH* (2006), the new European Community Regulation on chemicals and their safe use (EC 1907/2006).

It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances with the aim to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. At the same time, innovative capability and competitiveness of the EU chemicals industry should be enhanced. The benefits of the REACH system will come gradually, as more and more substances are phased into REACH.

At the 2002 Earth Summit in Johannesburg, an international agreement was reached that governments should adopt the *Globally Harmonised System of Classification and labelling of Chemicals (GHS)* by 2008 to simplify the global trade and to ensure a sound management of chemicals. These international criteria were agreed by the United Nations Economic and Social Council (UN ECOSOPC). In July 2007, the European Commission adopted the United Nations GHS for chemical substances and mixtures. The EU expects to be able to substitute the current EU classification and labelling system for chemicals (Directive 67/548/EEC, Directive 1999/45/EC and Directive 91/155/EEC in 2010 for simple chemicals and is expected 2015 for chemical mixtures).

Also in accordance with the Johannesburg implementation plan and Agenda 21, the *Dubai Declaration on International Chemical Management* (February 2006) promotes sound management of chemicals and hazardous wastes throughout their life cycle. The Dubai convention is determined to protect children and the unborn child from chemical exposures that impair their future lives.

Related to the children protection and as a specific example of the risk of chemicals at global level and in a circular economy, the toys market can be approached. Very recently, the European Commission has come forward with measures to improve toy safety in Europe. The Commission wants to strengthen EU-rules, especially those relating to the use of chemical substances in toys. The proposal aims at enhancing the safety of toys replacing and modernising the 20 years old Toys Directive 88/378/EEC of 3rd May 1988.

The revision has a threefold objective: first and foremost there will be new and higher safety requirements to cope with recently identified hazards, second it will strengthen manufacturers' and importers' responsibility for the marketing of toys and finally it enhances the market surveillance obligations of Member States. It will prohibit the use of chemical substances that are susceptible to provoke cancer, prohibit allergenic fragrances or oblige toy manufacturers to issue appropriate warnings to improve the prevention of accidents.

The RISKCYCLE project will influence policy issues at a global scale, not only in developing countries but also in developed ones and will create awareness and enhance state-of-the-art on risk-based management of chemicals and products among stakeholders.

The primary aim of RISKCYCLE is to identify future R&D needs required to establish a risk-based assessment methodology for chemicals and products that will help minimise animal testing while ensuring the dual aim of allowing the development of new chemicals and minimising risks for health and the environment. In order to achieve this goal, the first step will be to assemble and evaluate existing