Journal of Cleaner Production xxx (2015) 1–10

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

A tiered approach for environmental impact assessment of chemicals and their alternatives within the context of socio-economic analyses

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ARTICLE INFO

Article history:
Received 19 December 2014
Received in revised form
7 July 2015
Accepted 1 August 2015
Available online xxx

Keywords:
Socio-economic analysis
Environmental impact assessment
REACH
Substitution
Risk assessment

ABSTRACT

The European Union's REACH regulation has introduced Socio-Economic Analyses as a new decision support tool in the domain of chemical policy-making. This paper presents a pragmatic method to review the replacement of chemicals in processes or products in terms of the environmental impact. The aim of this work is to develop a broadly accepted method for environmental impact assessment as part of Socio-Economic Analyses. The method consists of a stepwise and tiered approach for Environmental Impact Assessment whereby the expected impact of the replacement of chemicals is assessed via Risk Characterization Ratios and toxic pressure quantification (expressed as a Potentially Affection Fraction of species), and – if relevant – via a Persistency, Bioaccumulation potential and Toxicity score. The working of the method is demonstrated by the replacement of chemical substances in detergents, gutters and Expanded Polystyrene. Of the three replacements, for gutters, the reduction of the toxic pressure on the aquatic compartment was highest. Based on 50% effect concentrations the Potentially Affection Fraction of species due to the use of zinc gutters was relatively high (15%), while it was 0.6% after replacement by PVC gutters. This indicates that PVC gutters have a lower direct impact on aquatic biodiversity than zinc gutters. This paper demonstrates that even with limited data the proposed method can be used to move from risk indicators to impact indicators. The tiered approach allows finding the most appropriate level of analysis in a cost and resource efficient way. The method allows comparison of results of different scenarios and as such allows selecting the most preferable alternative from an environmental perspective. This is useful in the context of socio-economic analysis and as such, this method is available as a decision-support tool under REACH and other chemical policy frames such as the United Nations Environment Program.

1. Introduction

Major developments are ongoing in the field of design, production, use and regulation of chemicals, with regard to associated risk concerns. Mankind uses chemicals to its benefit and profit. Despite this, there is currently a desire to minimize the use of man-made chemicals, especially the most risk-bearing ones. Contextually, due to accelerated urbanization and population growth, chemical production is still increasing with annual sales for instance doubling over the period 2000–2009, and expected production, and consequently emissions, rising (UNEP, 2012). Safe and sustainable use of chemicals asks for a minimized chemical footprint (Rockström et al., 2009), that is: the net expected impact of all man-made chemicals present in an area should not exceed a safe impact boundary (Bjørn et al., 2014; Posthuma et al., 2014; Zijp et al., 2014).

Comprehensive sets of policies have been developed to realize safe and sustainable use. They aim at regulating chemical emissions posing risks, or they focus on the risk management of contaminated environmental compartments and waste. The regulatory aim is always to protect man and ecosystems from undesired impacts, via prevention, risk reduction management or sanitation. The primary

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http://dx.doi.org/10.1016/j.jclepro.2015.08.003
0959-6526/

Please cite this article in press as: Bruinen de Bruin, Y., et al., A tiered approach for environmental impact assessment of chemicals and their alternatives within the context of socio-economic analyses, Journal of Cleaner Production (2015), http://dx.doi.org/10.1016/j.jclepro.2015.08.003

Abbreviations

AE	alcohol ethoxylates
BAU	business as usual scenario
DEHP	bis(2-ethylhexyl) phthalate
ECETOC	European Centre for Ecotoxicology and Toxicology of Chemicals
ECHA	European Chemicals Agency
L(E)C50	lethal (effect) concentration 50% (median)
EF	effect concentration
EIA	environmental impact assessment
EPS	expanded polystyrene
ERC	environmental release category
EUSES	European Union System for the Evaluation of Substances
HBCDD	hexabromocyclododecane
Kow	octanol water coefficient
LCIA	life cycle impact analysis
LC	lethal concentration
NOEC	no-observed effect concentration
NP	nonylphenol
PAF	potentially affected fraction of species
PBT	persistency, bioaccumulation potential and toxicity
PDF	potentially disappeared fraction of species
PEC	predicted environmental concentration
PNEC	predicted no-effect concentration
PS	policy scenario
Pvap	vapor pressure
QSAR	quantitative structure activity relationships
REACH	Registration Evaluation Authorisation and Restriction of Chemicals
SEA	socio-economic analyses
Sol	solubility
RCR	risk characterization ratio
SSD	species sensitivity distribution
TBECH	dibromoethyldibromo-cyclohexane
TCEP	tris (2-chloroethyl) phosphate
UNEP	United Nations Environment Program
vPvB	very persistent and very bioaccumulative
WWTP	waste water treatment plant

approach to avoid, limit or reduce undesired impacts is the option to restrict the production, use and emission of the more hazardous compounds based on chemical risk assessments. For chemicals with proven societal benefits, regulations may trigger so-called Socio-Economic Analyses (SEAs) in which benefits and costs of the use or either the non-use or replacement of a chemical in a certain application are estimated, weighed and valuated. In the European context, this is encompassed in the REACH regulation (European Commission, 2006) via SEA (see also Apitz et al. (2006)). The policy mandate for such analyses thus exists, but practical approaches lag behind. A framework for integrated impact assessment of chemicals was proposed by Briggs (2008) with regard to integrated environmental health impact assessment, whereas Crane (2010) reported on approaches for converting environmental risk assessment outputs into socio-economic impact assessment inputs within REACH. Askham et al. (2012) reported on a tool that was developed to combine environmental and economic indicators with REACH information, whereas environmental system analysis tools were reviewed by Finnveden and Moberg (2005). Despite these reports, and despite the framework proposed by Carvalho et al. (2014), currently there is no broadly accepted method for integrated impact assessment which encompasses the needs of socio-economic analyses as well as the needs phrased by the United Nations Environment Program (UNEP, 2012).

The REACH regulation has introduced SEA as a new tool in the domain of chemical policy-making. In practice, a detailed SEA shows the positive and negative impacts of a policy measure in comparison to alternative chemicals for the same use. This is helpful information in decision making on authorisation or restriction of chemicals. The European Chemicals Agency (ECHA) published guidance on SEA for so-called restriction dossiers in 2008 and a guidance on SEA for the authorisation process in 2011 (ECHA, 2008, 2011). These guidances define five different impact categories of the SEA: human health impacts, environmental impacts, economic impacts, social impacts and wider economic impacts. These guidances still leave various aspects of SEA open for interpretation and further development. Meanwhile, various efforts have been made to further define environmental impact assessment (EIA) as one of the impact categories of SEA under REACH. RPA (2011) presented a framework for the assessment of environmental impacts to be used in the context of REACH. This work provides a practical basis for EIA within the context of chemicals legislation and identifies e.g. physical indicators, dose response data and species sensitivity distributions (SSD) as models for EIA. The European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC, 2011) explored SEA, and pointed at a number of impact assessment options, whereby the outputs of risk characterizations can be linked to valuated impact categories by e.g. species sensitivity analyses, smart modeling, and linkage to methods derived under the concept of Good Ecological Status in the Water Framework Directive. Likewise, WCA-Environment (2011) suggested the use of Life Cycle Impact Analysis (LCIA), SSD and a more complex ecosystem services approach for EIA within the context of REACH and SEA. Further (methodological) development and testing of SEA parts (as the various impact categories) are currently still needed as usage of the proposed methods and models in practice appears difficult.

This paper aims to describe methodologies to select chemicals and supply chains with the lowest possible environmental impacts. To this end, the paper also aims to fulfill the need expressed by UNEP to comprehensively assess novel techniques and chemicals (UNEP, 2012). A pragmatic approach is presented and is now available to test the replacement of chemicals in processes or products, in terms of the impact of the hazardous chemical on the environment. The present work aims to (1) address the current limitations in designing a practical and comprehensive framework for comparative evaluation of chemical hazards in their impacts on the environment, (2) describe the design of such a practical framework, (3) test the framework by means of case studies, and (4) to stimulate discussion and ideas, recognizing the latitude for further developments.

2. Material and methods

An environmental impact assessment (EIA) method was designed, via data and concepts, for an SEA of chemicals based on the estimation of environmental toxic pressure of chemical emissions and the persistency, bioaccumulation potential and toxicity (PBT) of the chemical. The first was assessed via the use of SSDs (Posthuma et al., 2002) with toxic pressures expressed as the