Sustainability and Innovation

Sustainability and Innovation

Published Volumes:

Jens Horbach (Ed.)
Indicator Systems for Sustainable Innovation
2005. ISBN 3-7908-1553-5

Bernd Wagner, Stefan Enzler (Eds.)
Material Flow Management
2006. ISBN 3-7908-1591-8

Andreas Ahrens · Angelika Braun
Arnim von Gleich · Kerstin Heitmann
Lothar Lißner

Hazardous Chemicals in Products and Processes

Substitution as an Innovative Process

With Contributions of
Andrea Effinger, Matthias Weiß, Claudia Wölk

With 21 Figures

Physica-Verlag
A Springer Company

Andreas Ahrens
Ökopol
Nernstweg 32–34
22765 Hamburg
Germany
ahrens@oekopol.de

Kerstin Heitmann
Ökopol
Nernstweg 32–34
22765 Hamburg
Germany
heitmann@oekopol.de

Angelika Braun
Kooperationsstelle Hamburg
Besenbinderhof 60
20097 Hamburg
Germany
angelikabraun-hh@web.de

Lothar Lißner
Kooperationsstelle Hamburg
Besenbinderhof 60
20097 Hamburg
Germany
lissner_koop@public.uni-hamburg.de

Professor Arnim von Gleich
Universität Bremen
FB 04 Produktionstechnik
Postfach 330440
28334 Bremen
Germany
gleich@uni-bremen.de

This project was sponsored by the Federal Ministry of Education and Research under the funding program "Frameworks for Innovation towards Sustainability (RIW)" (project number 07RIW) – the authors assume sole responsibility for the contents of this report.

ISSN 1860-1030
ISBN-10 3-7908-1642-6 Physica-Verlag Heidelberg New York
ISBN-13 978-3-7908-1642-6 Physica-Verlag Heidelberg New York

Physica is a part of Springer Science+Business Media

springeronline.com

Printed in Germany

Cover-Design: Erich Kirchner, Heidelberg

SPIN 11544319 88/3153-5 4 3 2 1 0 – Printed on acid-free paper

Contents

Introduction

Damage and risks caused by mineral fibres, metal dust and organic chemicals all occur in the course of industrial history: lung cancer as the result of inhaling asbestos fibres; brain damage and cancer due to solvent vapours at the workplace and also in chemical cleaning processes; global dispersion and bioaccumulation of pesticides such as DDT and of industrial chemicals such as PCBs; of heavy metals such as mercury, lead and cadmium; destruction of the ozone layer due to CFCs as well as potential risks related to industrial chemicals with hormone-like effects (e. g. phthalates, TBT[1]) and the presence of potential carcinogenic acryl amide in French fries.

From the perspective of sustainability, the development of such problems is particularly relevant, as they are rather insidious and not immediately apparent, and may be detected too late and thus no longer be amenable to remedy. In the field of hazardous substances, this applies to those substances that are persistent (i.e. are not or are only very slowly biologically or photo chemically degradable), are mobile (gaseous, dust-like, soluble in water), and bio-accumulative and can thus disperse globally and/or accumulate in the biological food chains. Also substances that, even after a long delay, trigger serious health risks in the case of chronic exposure to small doses (e.g. cancer, diminished reproduction capabilities) should be mentioned here.

The history of endeavours to reduce such risks is just as lengthy as the history of substance-related risks. In doing so, state regulative practices initially concentrated on occupational health and safety, and later also on media-related environmental protection. It was not until chemicals legislation was introduced at the beginning of the 1980s that regulations also directly related to the production and marketing of hazardous substances. In all three areas of regulation, occupational health and safety[2], environmental protection[3] and chemicals regulation[4], replace-

[1] PCB: polychlorinated biphenyls, TBT: tributyl tin, CFC: chlorofluorocarbons

[2] Cf. e.g. the substitution principle in the German Ordinance on Hazardous Substances (§16 and §36). Please refer to ‘Technical Rules for Hazardous Substances´ TRGS 440 for the recommended procedure of substitution.

[3] Certain regulations contained in the air legislation and also in the annexes to the Waste Water Ordinance include the substitution of hazardous substances as the best available technology and thus attempt to put into operation the precautionary principle (cf. UBA texts 88/99, Guidance Manual for Formulators and Other Professional Users of Chemicals).

ment/substitution of hazardous substances by less dangerous substances is emphasised as a key element of risk management. Companies, driven not only by state regulation but also by well understood self-interest, were repeatedly faced with the question as to whether less dangerous substances could be used in individual applications.

In actual fact a great deal has also been undertaken in this area in the past. Many of the hazardous substances mentioned above have now more or less disappeared from the market. Some were banned (e.g. DDT, CFCs, PCBs), their functions now being performed by less hazardous substances. Other hazardous substances have at least been considerably curtailed in their use with safety requirements being imposed (e.g. chlorinated solvents, highly toxic heavy metals). This has also led to the reduction of risks emanating from hazardous substances in many areas.

The history of the substitution of hazardous chemicals could be considered a success story. If it is examined more closely, however, a range of as yet unresolved tasks are still evident (cf. chapter 6). This basically concerns two problem areas: the fundamental ability and willingness to substitute hazardous substances and the question whether the substitute is actually any less dangerous.

Considerable inertia in established practices can be observed everywhere, a tediousness and resistance to change, against which the substitution of hazardous substances has to struggle. Although in many cases the problems of hazardous substances are evident to a large extent, and although substitutes are available, indeed available for many areas of application, the substitution process is not progressing. The substitution of asbestos was a typically extremely tedious process (cf. chapter 2.2).

If we consider the process of hazardous substance substitution as an innovative process, what we are dealing with here is, firstly, a problem of a lack of willingness to innovate or a lack of the ability to be innovative. Secondly, the uncertainty surrounding the direction of innovation also plays a major role. Is the substitute substance in fact any less dangerous or does it entail new possibly as yet unknown dangers and problems – as was the case with the introduction of CFCs as a predicted low-risk substitute for ammonia as a refrigerant –?

The research project 'Options for viable innovation systems for successful substitution of hazardous substances' (or SubChem, for short)[5] was concerned with the problem of the ability to be innovative and of the direction of innovation with regard to risk reduction by hazardous substance substitution as part of the programme 'Framework conditions for innovation towards sustainability' funded by

---

[4] The VOC Directive (EU Directive 1999/13/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations) thus contains an obligation to substitute hazardous substances.

[5] FKZ 07RIW4, for further information cf. http://www.subchem.de. Information on the research program can be consulted at: http://www.riw-netzwerk.de

the Federal Ministry for Education and Research (BMBF)'[6]. The objective of this research project was to discover - on the basis of 13 case studies - under which framework conditions and in which constellations of actors the substitution of hazardous substances is encouraged or is impeded. In particular, this took into account the specific regulatory systems, the conditions on the markets as well as the ongoing public debate, in the course of which a series of substances hit the headlines as the so-called 'contaminant of the month'.

[6] The project partners were the Hamburg University of Applied Sciences (HAW), Ökopol – Institute for Environmental Strategies GmbH Hamburg and the Co-operation Office of the German Trade Unions Ass./Universities of Hamburg

1 Summary of most important results

By way of introduction, the most important project results are outlined here. Initially, the project focuses on the main issues, i.e. the ability to be innovative and the direction of innovation, and also on the current reforms in chemicals legislation taking place at EU level. After that, selected results are highlighted and explained.

1.1 Aspects of the ability to be innovative

The attempt to understand the frequently faced tediousness of substitution processes is firstly directed at individual actors[7], their motives and their opportunities for influence, and also at the way they utilise these opportunities or, rather, do not utilise them. The 'roles' of these actors can then immediately be sub-divided into promoters and blockers, and an attempt will then be made to explain the success or failure of substitution as a consequence of a certain distribution of interests and powers. In fact, it always comes down to people who promote or block innovations. This begins with the entrepreneurial personality as illustrated by Schumpeter, who performs its work of 'creative destruction', via 'entrepreneurs' who are said to be indifferent to occupational health and safety, consumer protection or environmental protection, to cultural pessimists and 'luddites', who always aimed to impede one technology or another.

With regard to innovation processes the significance and the direct effectiveness of individual committed promoters or blockers with their individual motives such as profit or occupational health and safety, consumer protection or environmental protection should, however, not be overestimated. Although committed promoters do play an important part in most substitution processes, a closer look at the individual case samples very quickly reveals their structural futility. Complex innovative processes cannot be moved by a limited number of actors or even by individuals alone. Many substitution processes simply do not progress, despite the fact that we cannot observe any definite 'opponents'. These innovations are not impeded, they only become stuck, as the 'inertia of the system' is simply too high. In order to gain an appropriate comprehension of the ability (and not just the

[7] According to the German word `Akteure´, `actors´ in an innovation system means manufactures, importers and users of chemicals (actors in the supply chain, economic actors) as well as authorities, science, public interest groups and other participants outside the supply chain (cf. Figure 1).

willingness) for hazardous substance substitution (the ability to be innovative), we therefore must not solely look at individual participants in a supply chain, their interests and opportunities for influence. It is more important to have an overall view of the in some cases highly complex 'constellations of actors', including the 'framework conditions', which have an either encouraging or preventive effect on substitution processes as legislation, competitive conditions and public debates (cf. Figure 1). This is the reason why a system-theories approach was chosen in the SubChem project and the concept and heuristic model of 'innovation systems' was used. Overcoming the pure actors' perspective may contain in itself the risk of losing the action relevance of the expected results. Nevertheless a differentiated systems view should improve retroactively the individual actors' opportunities for action considerably. If the participants are able to develop a differentiated 'system comprehension', they can also better exploit their (albeit limited) opportunities for influence.

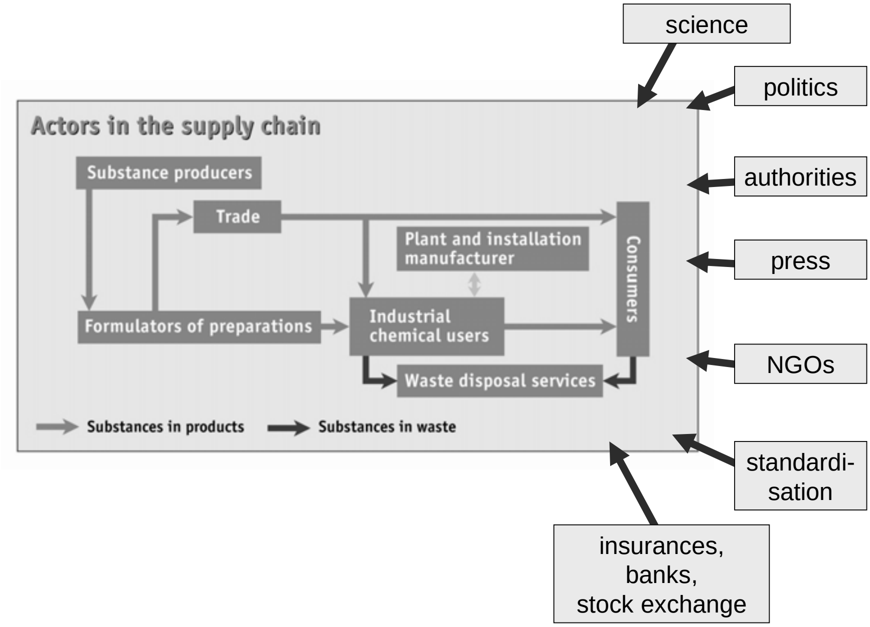

Figure 1. Actors in the innovation system: inside and outside the supply chain

1.2 Aspects of direction of innovation

Misguided substitutions such as the introduction of CFCs as a 'safe' substitute for ammonia as a refrigerant were already mentioned in the introduction. The example of CFCs may be an extreme case. But also the case studies examined in the project such as ‘the substitution of asbestos by non-bio soluble mineral fibres in construction uses’ and also ‘the replacement of inflammable hydrocarbons by non-inflammable chlorinated hydrocarbons in metal cleaning’ are examples of the existing major problems in orientation with regard to the direction of innovation. These uncertainties slow down many substitution processes additionally. Many substitution processes are also not developed precisely as there is widespread uncertainty as to whether the substitute really does help reduce risks. The latter is certainly so in the case of plasticisers in PVC products, where incomplete toxicological knowledge was quoted as an argument against substituting DEHP by citrate esters in sensitive applications, and at least partly in the case of resistance against the criterion “bio solubility” in the substitution of mineral fibres. The realisation from the case studies that the opponents of an innovation are too prone to utilise the (fatal) argument of insufficient knowledge in case of conflict also demonstrates only the tip of the problem from the position of the participants. The endless passing on of non-realisable ‘risk or non-dangerous burdens of proof’ is doubtless a game that is as futile as it is widespread. The industry’s lack of responsibility can be denounced or troublesome demands for substitutions can also be blocked ad infinitum. Nevertheless, the lack of certainty in orientation in the substitution of hazardous substances is not a motivation problem, but rather it is the problem of dealing with lack of knowledge, which can only be resolved structurally, in an appropriate way.

To be precise in many cases we know just as little about the problematic side effects and consequential effects of substances that have already been employed as we do about the alternatives. In practice, however, comparable uncertainties appear to have completely different effects. They generally have a greater effect against substitution and/or the substitute[8]. Especially in the case of planned changes in common (and possibly highly problematic) practices to date, it is easy to highlight the many uncertainties related to innovation. The innovator is generally faced with the obligation to demonstrate a greater ‘burden of evidence’ than parties wishing to leave things as they are. The uncertainties have the structural effect of discouraging innovation, even if they are not especially ‘exploited’ by participants[9].

However, the problem of an appropriate way of dealing with incomplete knowledge and major uncertainties is not only present in the case of hazardous substance substitution. This is a fundamental problem for any innovation. In this

[8] Current European chemicals legislation even amplifies this problem. Substances marketed in Europe after 1981 (or new substances, as they are called) are subject to high demands in respect of (eco)toxicological chemicals testing, while those substances already existing on the market at this time (or existing substances, as they are called) may continue to be used without any testing. This differentiation is no longer applicable in the run-up to the new EU chemicals policy (REACH).

[9] If certain substances are brought into ‘disrepute’ amid great public attention, the reverse effect is however sometimes also observed. Based on the principle of ‘anything but this substance’, any alternative may gain a structural advantage.

respect innovation and risk are inseparably interlinked. Substitution of hazardous substances is not fundamentally different from other forms of innovation. Companies had to learn to deal rationally with the economic risks, which is also just as applicable when dealing with technical, health and ecological risks. Knowledge about risks and hazards is restricted and incomplete in all these areas. Thus ways of dealing appropriately with the remaining uncertainties have to be developed.

In addition to the general systems inertia already mentioned, the uncertainties that always remain in view of all innovations represent significantly ‘more effective’ barriers to innovation than all positive or negative motives and interests of the participants, which could be ascertained in the various case studies. The need to focus on innovation systems at supply chain level as well as overcoming system inertia and uncertainties and/or lack of knowledge, as fundamental barriers to innovation are some of the important findings of the SubChem project[10]. However, this in turn produces new questions.

1. What does flexibility and/or inertia of innovation systems depend on (the ability to be innovative)?
2. What opportunities exist, despite the remaining major uncertainties, to promote innovations and/or the substitution of hazardous substances successfully and in the appropriate direction (dealing with lack of knowledge, decision on direction of innovation)?

1.3 Model of “innovation systems at supply chain level”

Comparatively early on in the research process a heuristic model of ‘innovation systems on supply chain level of hazardous substance substitution’ was developed in co-operation with the two other ‘chemicals projects’[11] in the research programme. In this model, the supply chain forms the central point and four main influencing factors affect the system: the regulative pull of application-related legislation in the area of occupational health and safety; environmental protection and consumer protection; the regulative push of chemicals legislation (regulations governing market entry); the pull of market demand and the push of scientific/technical developments, which continually present new solution options (cf. Figure 6, Chapter 3.3.2).

The SubChem research process took place in a constant process of interaction between a deeper analysis of the system and understanding of the system and the empirical studies on cases. The cases are neither self-explanatory nor is innovation research already so far advanced that hypotheses derived from an established and

[10] These findings are not necessarily surprising. They tie in well with the everyday experience of all ‘innovators’, all ‘entrepreneurs’, who really wish to carry out an entrepreneurial activity, but also all political reformers, revolutionaries etc.

[11] Within the :[riw]-framework three research projects were engaged in issues related to chemicals legislation: SubChem, COIN and INNOCHEM (cf. http://www.riw-netzwerk.de/projekte/riw_00_02_00.htm)

recognised set of theories would only require ‘empirical’ verification. In the case studies theoretically based hypotheses from the system view could be examined empirically in descending abstraction (i.e. deductively) and, conversely, hypotheses about the significance of certain constellations of framework conditions, actors and their opportunities for influence were able to be generalised from the case studies in ascending abstraction (i.e. inductively). Both abstraction directions can only be differentiated as an ideal type; they are always interlinked and they have also been passed through iteratively several times in the course of the research process. In this way, with regard to the subject “the ability to be innovative”, two types of results were developed: on the one hand an improved ‘systemic’ perception including a differentiated model of the innovation system and, on the other hand, a set of hypotheses about the effects (and/or possibilities of effects) of certain framework conditions and actors.

1.4 Current developments in chemicals regulation

If the current regulative framework conditions in the area of hazardous substances are examined critically under the aspects of both health and environmental protection and also with regard to the effects on the ability to be innovative and on the direction of innovation, the conclusion may be reached that the current reform of EU chemicals legislation in accordance with REACH[12] is indeed a step in the right direction. The predominant regulation of chemicals’ application conditions, initially from a historical aspect, (i.e. regulation pull in our model of innovation system) suffers greatly from the diversity of the specific situations, with the result that there is an excessive deficit in implementation. In this respect, it is entirely logical to create a more regulative approach for the marketing of chemicals (i.e. regulation push in our model of innovation system) and from this approach also to move on to the application conditions (or the various exposure scenarios, respectively). REACH also compensates for some of the current serious structural disadvantages of new substances (and/or the trend to prefer existing substances, which curbs innovation). The (risk) communication along the supply chain promoted by REACH lastly supports the long-overdue re-orientation of innovation systems, which are still too branch-specific. The chemical industry had always seen itself as a substance manufacturer and had organised itself accordingly. The important innovations, which were the reason for the strong competitive position of the German chemical industry up to the 1960s and 1970s, were in fact essentially developed in laboratories[13]. Frequently at that time a new interesting substance was first synthesised, after which the search for possible lucrative areas of application was

[12] REACH is an acronym comprising the most important elements of the new chemicals legislation at EU level: *Registration, Evaluation and Authorisation of CHemicals*, cf. http://europa.eu.int/comm/enterprise/chemicals/chempol/whitepaper/reach.htm

[13] Cf. Grupp et al 2002, Dominguez-Lacasa et al 2003