Experience with Chemicals Regulation – Lessons from the Danish LAS Case

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Abstract: *Chemicals regulation is under pressure for change, and lessons from former experience are important to inform the process. This paper is based on a case study of the Danish measures towards regulating a specific substance, Linear Alkylbenzene Sulphonate (LAS), and the case is used to deepen the understanding of how chemicals regulation is being shaped through social and political processes, and which lessons can be drawn regarding the effectiveness of different regulatory measures. We outline briefly the history of the chemicals regulation as a background for the detailed discussion of the case study. Finally, we present a few tentative proposals for future changes of the chemicals regulation and conclude with relating the case to the ecological modernization discourse.*

Keywords: Chemicals regulation, LAS, ecological modernization, social studies of science.

1. Introduction

Chemicals regulation is currently a contested issue. More than 100,000 substances are in circulation worldwide, and only a very few (approximately 5,000) are under regulation (Nordbeck and Faust 2003). In the EU White Paper on chemicals regulation (Comm. 2001) – which launched the process towards the present reform, REACH – the Commission concedes that existing regulation, with few chemicals being reported and assessed, is sorely inadequate. The White Paper argues that an effort is needed to move towards improved regulatory control of the many chemical substances that are not subject to approval, because they were marketed before prior approval became mandatory. Public concern about the many unregulated chemicals is increasing, as new insights concerning environmental and health issues associated with the production and use of chemicals continue to emerge, highlighted, for instance, by the increasing focus on endocrine disrupters over the past few years. Nowadays, when chemicals regulation is highly disputed at the political and administrative levels in the EU, there is a need for research to consider the regulatory experience from previous years so as to form a basis for drawing lessons for improving future regulation. However, the field of chemicals regulation is somewhat overlooked in environmental policy studies compared to many other issues, so the intention with this paper is to make a small contribution to filling the gap.

The basis of the paper is a case study of the Danish measures towards regulating a specific substance, Linear Alkylbenzene Sulphonate (LAS) (Lauridsen

2002). In the late 1990s and the early 2000s the regulation of LAS was one of the really contested issues in Danish chemicals regulation, so we decided to explore the discussion and to use the case as a basis for considering two research questions: Firstly, how is chemicals regulation being shaped through different social and political processes? Secondly, which lessons can be drawn from this case regarding the effectiveness of different regulatory measures? The study is based on a combination of literature studies, public documents, and interviews with relevant actors (see final acknowledgements). The case turned out to be a good illustration of the complexity of the formation of chemicals regulation and of an unfortunate trend towards diffusing political responsibility. Whilst Denmark was one of the few pioneers in regulating LAS, the experience was not encouraging. But we have tried to use the experience to draw constructive lessons.

Theoretically, the study was inspired by a combination of fields. Obviously, some knowledge of chemistry has been necessary, but the research interests of the paper are mainly motivated by perspectives coming from the social sciences. These perspectives apply ideas from political science and sociology, including the debate on ecological modernization, and the field of social studies of science. Inside the framework of social studies of science, the studies of chemicals regulation have mainly dealt with risk assessment, risk management and scientific uncertainty (Cf.: Bal and Halffman 1998), and they are thus complementary to political science studies of the development of chemicals regulation, which have focused more on the historical formation of the regulation (e.g. the study by Brickman et al. 1985). The debate on ecological modernization provides a framework for discussing more recent trends in environmental regulation and how chemicals regulation fits into these more general trends. Historically, the regulation of chemicals developed separately from the regulation of other environmental issues, and this separation was reinforced by the varying degree of EU intervention, as chemicals regulation was early in becoming subject to EU intervention and harmonization, while environmental regulation largely remained under national jurisdiction for far longer. Lately, however, chemicals and other environmental policies have become more closely related, and some of the regulatory instruments associated with ecological modernization are applied in both sectors.

The following section of the paper outlines the history of the chemicals regulation, as this is necessary to understand the background of the LAS case and the discussion of the lessons to be drawn. The third section provides a chronology of the LAS case, followed by a fourth section with a thematic discussion of the formation of this specific regulation. It should be emphasized that it is not within the scope of this paper to determine whether LAS is harmful or not, and furthermore, that we do not intend to make any value judgements regarding the actors in this case. The fifth section presents a few tentative proposals for future changes of the chemicals regulation, and in the final section we conclude with some theoretical reflections related to the ecological modernization discourse.

2. Historical Background

Before dealing with the specific story about how the regulation of LAS came about, this section outlines the more general history of chemicals regulation. Although the details relate to Denmark, most of the outline is also valid for other western countries. The structure of the outline is inspired by the study of chemicals regulation in four countries (US, UK, France, and (former) West Germany) by Brickman et al. (1985). In the introduction to this study the authors summarize a broad array of political science literature to identify the significant conditions and factors shaping chemicals policies and influencing their relative efficiency. The aim of the authors was to compare chemicals regulations between the countries, to assess which type of regulation appeared to be the most efficient, and, more specifically, to identify possible inspirations for the future modifications of US regulation.[1] Based on their literature survey, they arrived at four aspects that are important when characterizing the chemicals regulation of different countries:

- the organizational set-up and procedures of their national policy bodies
- the way scientific information is produced and applied
- the political strategies of private stakeholders
- the impact of policies of international organizations.

These aspects can be transformed into a dynamic approach, as they also pinpoint conditions for and

sources of change. In the analysis of how the regulation of chemical substances evolve, we have thus chosen to consider the interaction between the following three aspects, which have much in common with the list above:

- *The understanding of environmental issues.* The dynamics of chemicals regulation is obviously influenced by specific experience with chemicals and by developments in scientific insights, and changes in the way such insights are obtained is also important.
- *Pre-existing regulation.* Both the pre-existing national regulation and the framework set by international policies constitute important conditions for change, by promoting some forms of action and regulatory strategies and by restricting others.
- *The organizational set-up of contemporary political processes.* The way political processes are organized and the role of the media in these processes, influence the scope for various stakeholders to influence policies.

These three aspects serve as a structural framework for the following historical overview of the chemicals regulation and to the thematic discussion of the LAS case. Regulation evolves through a constant interaction between the three aspects, so a simple phase model implying that new scientific understandings lead to political action and then to rational regulatory measures would not make much sense.

The Understanding of Environmental Issues

Chemicals regulation has evolved as a gradual branching process, as accidents and disasters revealed new chemical hazards and effects (Basse 2001). Traditionally, the process has been based on experience, and only in the 1950s were the first steps taken towards a more science-based approach, with the development of human toxicology. In particular, this was reflected in the regulation of carcinogenic substances and foodstuff additives. Though later followed by science-based regulation in other sectors, chemicals regulation has essentially remained experience-based (Bro-Rasmussen et al. 1996).[2]

The experience- and science-based approaches have both been based on single-substance regulations, reflecting the predominant working method in chemical science, i.e. developing and characterizing chemicals one by one. This approach implies a simplification of problems, in agreement with the prevailing reductionist scientific tradition (Harremoes and von Krauss 2001a, Harremoes and von Krauss 2001b). Over time, the single-substance approach combined with a growing number of chemicals gradually necessitated a prioritisation of regulatory efforts, enabling regulation to address the substances considered the most hazardous. This prioritisation reflects a gradual development in our understanding of environmental issues, towards today's use of effect categories, including PBT (persistent, bio-accumulative, and toxic), vPvB (very persistent, very bio-accumulative), and CMR (carcinogenic, mutagenic, and reprotoxic). Most recently, it has been debated whether to add effects stemming from endocrine disruptive and allergenic properties to the categories already covered by chemicals regulation. The discovery of endocrine disruptive and allergenic properties reflects a broadening understanding of environmental issues, from an initial preoccupation with the effects of short-term and direct exposure, towards inclusion of long-term effects and indirect exposure (Bro-Rasmussen et al. 1996).

Historically, chemicals regulation was first evolved to meet the need to control health hazards. Environmental aspects were not addressed by the chemicals regulation until the inclusion of environmental considerations in 1979, when ecotoxicology was developed as its scientific basis. The relatively late adoption of environmental considerations reflects the fact that historically, environmental and chemicals regulation evolved "compartmentalized", as two separate bodies of regulation: chemicals regulation to control health hazards by bans on single substances and restriction on use, and environmental regulation to control the emission of chemicals in relation to industrial production through standards etc. (Engberg 1999, Jørgensen and Boye 1998). Health hazards have remained the overall focus of today's chemicals regulation, and environmental concerns are evident as an extended view of hazards to human health, rather than actually addressing effects in the ecosystem at large.[3] Moreover, regulatory efforts have been disproportionately distributed between "environmental compartments", with a considerable body of standards and harmonized rules for the aquatic environment, compared to those covering the terrestrial environment. This reflects the fact that the need for including environmental considera-

tions first emerged (in 1979) from problems in the aquatic environment (due to a dispute between the Netherlands and Germany on the environment of the River Rhine), while the terrestrial environment was not included until the 1990s, spurred by concerns over the possible environmental problems of reusing sewage sludge in agriculture (Rank 1999).

Both environmental and chemicals regulation use the term "xenobiotic substances" to distinguish naturally occurring substances from substances found in the environment as a result of human activity. This differentiation gained ground in the 1980s – as a concretisation of observations and thoughts in Rachel Carson's book, "Silent Spring" (1962) – and reflects an increased focus on the variety of chemical substances present in household and industrial products.[4] Since it is important to our case study, the concept of xenobiotic substances will be introduced in more detail below.

Naturally occurring substances include substances such as SO_2 and CO_2, which form part of natural substance cycles and in naturally occurring amounts have no hazardous effects on humans and environment. However, antropogenous activity generates elevated amounts of such substances in the substance cycle, with impacts such as acid rain and global warming. Regulation can be complicated by the difficulty of determining a background level for these substances, their concentrations already elevated. By contrast, substances defined as "xenobiotic" are synthesized chemicals, present in many manufactured products, which are discharged to nature with e.g. household and industrial wastes. For these substances even small quantities might be hazardous. Our understanding of risks and effects related to xenobiotics has evolved over time – from the assumption that structural similarity between naturally occurring and synthetic substances is a criterion of harmlessness, to a recognition (following the discovery of hormone disruptive and allergenic effects) that structural similarity with naturally occurring substances can also be an indicator of harmfulness, since organisms will respond to the biochemical signals of xenobiotics as though they were natural. At present, there is a dawning general recognition that no chemicals can be considered harmless.[5]

Another recognition with bearings upon the case study is that waste treatment is not just a way to prevent environmental problems, but may itself cause new environmental problems. As a result of population growth and increased waste production in the 20th century, waste treatment became necessary in the 1960s and 1970s (Engberg 1999). In Denmark, wastewater treatment became the environmental strategy of the 1970s, when the marine environment was threatened by the discharge of untreated sewage water directly into the sea (Danish EPA 1995). However, the water treatment plants eventually generated new environmental problems, as they produced huge quantities of sewage sludge which, when deposited or incinerated, caused both capacity and environmental problems, also due to dispersal of xenobiotics in the environment.

Current changes in problem understandings are moving towards a recognition of ignorance as a fundamental condition for science, and that we can still be surprised by new effects (cf.: Wynne 1992) Moreover, the inherent uncertainties of interpreting scientific data are increasingly accepted. This prompts questioning of the widespread confidence in scientific knowledge as the basis of regulatory initiatives, since experts are unable to quantify and predict chemical effects and hazards (cf. Yearley 1997; Cortney 2000). However, there is considerable disagreement on this view, not least because a reduction of chemicals use would entail considerable socio-economic and production-related costs. One regulatory attempt to deal with the issue of scientific uncertainty is the introduction of the precautionary principle, enabling political initiatives based on assumed and plausible risks. The actual mandate of the precautionary principle is, however, limited by disagreement among actors on its interpretation and operationalization (Bro-Rasmussen 2002).

Pre-Existing Regulation

Apart from illustrating how our understanding of health hazards and environmental risks has emerged, the dual structure of chemicals regulation also reflects the varying degree of EU harmonisation applying to the relevant legislation. Present chemicals regulation consists of two acts: the Act on Chemical Substances and Products[6] is a common European, all-harmonized set of laws, while national environmental acts are implemented EU directives in the form of minimum requirements.[7] The purpose of national environmental acts is the local regulation of production-related issues, while the harmonized

chemicals act regulates chemicals as a commodity subject to international trade. Its primary aim is to protect European producers of chemicals against technical trade barriers – a concern that carries considerable weight in regulation (Bro-Rasmussen et al. 1996). As a consequence of total harmonization, individual EU member states are restricted to make national regulations on chemicals within the scope given by the environmental acts, and on the basis of these, individual member states cannot, in practice, use instruments such as bans and limitations on use. In particular cases, individual member states have introduced national bans, but the number of successful attempts are very few compared to the large number of unregulated chemical substances (see examples in Jørgensen and Boye 1999).

The Act on Chemical Substances and Products rests upon a system of approved lists and black lists.[8] Unfortunately, this structure leads to a grey zone of unregulated and unassessed chemicals, comprising the vast majority of 100,000 chemicals, whose marketing and use are largely allowed without mandatory prior assessment or notification (Bro-Rasmussen et al. 1996).[9] As an attempt to handle the unassessed and unregulated chemicals, the EU risk assessment scheme was established in the 1990s, but since the scheme is based on single-substance assessments, the process is exceedingly slow. Other factors contributing to the slow progression are: the fact that the investigations related to risk assesment are time-consuming (and expensive), the fact that the risk assesment requires consensus among EU-member states, and the fact that stakeholders may benefit from protracting the process by lobbyism and opposition. According to an estimate by the Swedish Society of Nature Conservation, assessing all unassessed chemicals would require approximately 15,000 years, given the present framework of the scheme (Swe. Soc. Nat. Cons. 2003). A more 'optimistic' estimate of 2,000 years is referred to by the Danish EPA.[10]

The Organizational Set-Up of Contemporary Political Processes

Since the 1950s there have been fundamental changes in how political processes take place in western societies. In the following, we point out three circumstances that have influenced (and to some extent been influenced by) the evolution of chemicals regulation:

1) The new part played by scientific experts in relation to political processes
2) The changed societal conditions for political parties, and hence for the political influence of the media
3) The emergence of "the political consumer".

It has been pointed out as an overarching trend that political dependence on scientific consultancy has gradually increased for a number of sectors – from security politics to new technologies – due to the increased complexity of the problems involved (Haas 1992). For the chemicals sector, as mentioned above, the inherent complexity of chemicals regulation forced the evolution of a scientific regulatory basis as early as the 1950s. This evolution gave rise to new forms of interaction between experts and politicians (Jasanoff 1990). Since experts do not deliver knowledge and statements as raw data, but instead as an interpretation, they are able to influence decision-making by their choice of perspective, upon which their interpretation will be based. Their influence can also assume more organized forms, e.g. through more or less spontaneous formation of networks of professionals and civil servants sharing specific problem understandings – cf. the theories of epistemic communities (Haas 1992). Conversely, over the last decades, scientists have also become increasingly dependent on being able to deliver what politicians consider relevant insights, because research funding is coming under increasing political control. To provide funds for research, scientists must be able to demonstrate that they are working with significant problem areas, where research is needed as a basis for decision-making (Gibbons et al. 1994). Due to the increased political influence of the media (see below), scientists may be forced to market their results through the media. In the field of chemicals regulation, the case of endocrine disrupters exemplifies both the importance of an epistemic community for promoting new insights (Løkke 1998) and the importance of media coverage for research funding.

In the post-World War II era, changes in economic structures (e.g. changing occupational patterns, greatly improved general education, and the emergence and development of the welfare state) have caused the social basis of the political party structure to disintegrate. Concurrently, new political issues have come up, in which standpoints are not immedi-

ately derived from traditional distributional conflicts – with environmental issues as the most obvious showcase. These societal changes opened up to the emergence of new catchall parties, also paving the way to a completely new position for the media in the political process. Via the media, individual politicians and political parties can capitalize on single issues, and the media gain more political influence as a mechanism selecting issues with media-appeal. The rather more central role of the media as a platform for political processes implies that decisions are more often initiated by sudden accidents (e.g. disasters and shock), which help redirect public and political attention to new problems. This tendency is reflected in the branching process of the chemicals regulation. The media influence the political process, both as an arena in which actors may present their opinions and as an independent player with the explicit interest of creating marketable news. Apart from exerting their influence by selecting which news and stakeholders will be heard, the media also have active power to assign the roles of victims, "bad guys and good guys" among the actors involved (Breck 2001).

In the past, individual citizens would relate to politics through their right to vote. Today citizens are encouraged by different actors to signal their points of view through their consumption habits, with environmentalism as a key area for political consumption. In recent years, eco-labelling schemes have been applied in the chemicals area, and environmentalist and consumer NGOs are calling for more transparency regarding the chemical composition of consumer goods, in order to improve consumers' possibilities for making environmentally-friendly choices. Since scientific insights in environmental and chemical problems are far from commonplace, a political consumer will necessarily have to rely on guidelines provided by those who are more knowledgeable. This makes confidence a core issue of the environmental discourse. As amply demonstrated by the British BSE case, reliability has become a specific political goal, the achievement of which both politicians and bureaucrats depend on.

The general history as it has been told in this section will in the following section serve as the framework for presenting and discussing the specific regulation of the substance LAS. The three interacting aspects in focus of our analysis are: understandings of environmental issues, pre-existing regulation and the organizational set-up of contemporary political processes.

3. The Chronology of the LAS Case

The substance LAS[11] belongs to a group of chemicals known as surface active agents or surfactants, which share the ability to reduce surface tension between two immiscible phases. Due to this property, surfactants are used as an ingredient in detergents and cleaning products, where they contribute to the cleaning process by increasing the water solubility of fat and dirt. LAS belongs to the most used surfactants worldwide. In 1998, the Danish consumption alone was 3000 t.[12]

Investigations of the human and ecotoxicological effects of LAS demonstrate no troublesome effects in humans (such as reprotoxicity and cancer), apart from the ability to cause minor skin irritation. In contrast, in the presence of LAS, acute mortality and behavioural changes have been observed in water and sediment living organisms in the aquatic environment. These effects result from the surfactant properties of LAS, which cause the organisms' cell membranes to dissolve (cf.: Kusk 1997, Damborg and Thygesen 1991). Moreover, LAS can increase the mobility in soil of other substances, and is also suspected of boosting the harmful effects of other chemicals via a so-called synergetic effect.

LAS was developed and introduced in the 1960s as an easily biodegradable alternative to the surfactant tetrapropylene benzene sulphonate (TPBS), which – due to its low degradability – caused foam build-up in the aquatic environment. Concerns over TPBS grew out of an aesthetic problem understanding (the foam looked disgusting and unnatural), and a technical solution was sought, based on the assumption that substitution of TPBS with a more easily degradable substance would prevent foam formation (Damborg and Thygesen 1991).[13]

In 1975, the TPBS problem resulted in a Danish ban on detergents and cleaning products containing surfactants with a biodegradability of less than 90 %.[14] A decade had passed since the problem was first recognized until the ban was introduced and the industry began to develop the earliest substitutions. This time lag enabled the Danish authorities and the industry to co-operate on solving the problem:

Not only did the industry get a chance to adapt to the new statutory requirement in advance, but also to lead the way.[15]

However, the statutory requirement only concerned the aerobic degradability of ingredients in detergents and cleaning agents, so later when the substance was found to have a low anaerobic biodegradability, LAS re-emerged as an environmental issue. LAS was once more placed on the agenda in the mid-1990s, and this time due to the development and crossing of two new understandings of environmental problems in general. One problem understanding was related to the term "xenobiotic substances", denoting not naturally occurring chemicals from household and industrial products that can find their way to the natural environment and generate a variety of effects in both humans and environment. The other problem understanding to evolve was that (residual) products from waste treatment could cause new environmental problems. Among other things, the crossing of both problem understandings prompted several mapping studies, and it generally alerted scientists and the public to the potential presence of xenobiotic substances in the environment due to waste water discharge and sewage sludge disposal (cf.: Christensen et al. 1990, Gustavson et al. 1994, Grüttner and Jacobsen 1994, Hansen and Busch 1990, Jepsen and Grüttner 1997, Kjølholt et al. 1995, Vikelsøe et al. 1996).

In Denmark, nutrients in sewage sludge from municipal sewage treatment plants are reused as fertilizer in agriculture, so the increased attention on xenobiotics in sewage sludge caused concern among farmers. This practice for the disposal of sewage sludge is in accordance with a general principle in Danish environmental law that recycling of wastes should take precedence over incineration and disposal. However, farmers now feared that the practice could lead to spreading of xenobiotics, thus deteriorating soil quality and crops. Their concerns caused the Danish Environmental Protection Agency to launch a series of initiatives. In 1995, they initiated a screening survey of 124 chemical compounds and substances, with the purpose of mapping xenobiotics' content in sewage sludge and assessing their potential effects (Kristensen et al. 1996). Based on the survey, LAS was classified as one of four groups of xenobiotics, for which spreading via sewage sludge could influence soil quality.[16] In conclusion, the investigators recommended a regulation of the four substance categories, and subsequently, in 1996, the Danish environmental authorities set cut-off values for the LAS content in sewage sludge, implying that sewage sludge with a higher LAS content could no longer be recycled in agriculture.[17] Simultaneously, LAS was included on the Danish List of Undesirable Substances, a national attempt to call attention to a few of the thousands of unregulated chemicals, which were used in large quantities in Denmark and the EU. The list has a double purpose: influencing procurement agents and producers to abstain from buying and producing products containing undesirable substances, and to reduce the Danish consumption. Moreover, the list serves to signal the Danish position on the relevant chemicals to other EU members.[18]

However, as a consequence of the cut-off values, the problem was passed on to the municipalities, now left with considerable quantities of sewage sludge, they could no longer dispose of. Incineration and depositing were not alternatives since, according to a principle in the Danish Environmental Act, these waste disposal strategies are of lower priority. In 1999, Danish EPA therefore adopted a two-part products-orientated strategy, consisting of a consumer-aimed campaign and a producer-aimed subsidy scheme. The latter was combined with mandatory reporting of current knowledge of constituents in washing powders and cleaning agents. The strategy thus proposed to stimulate companies to develop and produce non-LAS products in Denmark, and to influence the market for non-LAS products by encouraging consumers to purchase them. Characteristically, until this shift in regulatory strategy, the chemical industry and soap producers had been unaffected by LAS regulations, and it is worth noting that Danish EPA abstained from laying down environmental criteria for LAS substitutions and/or final products. In the view of Danish EPA, producers are competent to lay down such criteria on their own. This view does not take account of uncertainties due to varying expertise, levels of knowledge and perception of harmfulness among Danish producers.

The consumer-aimed campaign caused the problem to be passed on once more: from the municipalities to the consumers. As a result, the design and efficiency of regulation now hinged on consumer choices, resulting, among other things, in a com-

petition for the consumers' attention through the media. A debate ensued, with Danish EPA, NGOs, consumer organizations, retail trade, and industry as the principal actors, all trying to influence regulation by exploiting the consumers' need for confidence-building guidelines for their consumption choices. In the case of LAS, the definition of harmful or harmless is ambiguous due to diverging perceptions of harmfulness among the actors.[19] Based on these perceptions the actors could take opposite stands, so authorities, consumer and environmental organizations considered LAS harmful, whereas industry regarded LAS as harmless.[20]

The media debate is characterized by the comparative absence of scientific experts,[21] despite the fact that several experts disagree with the Danish EPA on the LAS regulation. Not that they consider LAS harmless, but as the most thoroughly investigated detergent, the substance is the best choice in environmental terms, which – for lack of knowledge – would risk being substituted with more harmful alternatives.[22] Some experts hold that the effects on the aquatic environment of LAS residues in treated wastewater pose a more serious threat than the effects on the terrestrial environment of LAS in sewage sludge.[23] In the aquatic environment, LAS accumulates in the sediment from where it is released over time, causing a long-term exposure of water- and sediment-living organisms. In its consumer aimed campaign, Danish EPA emphasizes the effect on the aquatic environment as their principal argument for purchasing non-LAS products. However, the cut-off values for LAS set by the practical regulation reflect no such concern. Instead, cut-off values appear to have been set with the purpose of reassuring agriculture of the potential health hazards – incidentally, a concern unconfirmed by scientific knowledge.

As manifest by the huge number of publications on the substance and its effects, there has been a massive scientific interest in LAS, not only in Denmark, but also in other EU countries, USA and Japan (cf.: Jensen 1999, Reemtsma 1996, Scott et al. 2000). This research has to a great extent been funded and/or conducted by the chemical industry and soap producers. Investigations carried out in Denmark have been closely linked to the Danish regulation addressing effects in the terrestrial environment. One among several attempts to find a technical solution to the LAS problem was to treat the sludge under aerobic conditions before dispersal to the fields. The procedure proved effective in terms of reducing LAS content, yet was found to inhibit degradation of other substances (Danish EPA 2001). An overarching feature of the tested technical solutions is their focus on single substances, ignoring the diversity of chemicals present in sewage sludge.

Overall, the massive interest in a single substance (LAS) displayed by authorities and industry is in glaring contrast to their lack of interest in the diversity of xenobiotics present in wastewater and sewage sludge, and in the complexity of the issue.[24] The number of xenobiotics is not limited to chemicals used in products, but also includes an unknown number of degradation products. The complexity of the issues is due to the fact that effects and exposure vary according to conditions in the recipient: season and precipitation combined with the physico-chemical parameters of acidity, concentration, and temperature, and according to the species, health condition, and age of exposed organisms. Effects may also be aggravated or inhibited by other chemicals present in the recipient.

A point worth noting is that the LAS-related problems necessitating regulation – only to be realized and regulated in the 1990s, when the two problem understandings crossed – could have been predicted in the 1960s when LAS was first introduced. The properties that make LAS desirable as a detergent are precisely the properties that give rise to toxic effects and accumulation in sludge and sediment. However, as already mentioned, the decisive shift of focus in regulation towards considering anaerobic degradation as well, had to await new scientific problem understandings.[25]

To put the Danish experience in perspective, we add a few remarks on the approach to LAS in Sweden.[26] Here a close cooperation between authorities, retail trade, environmentalist and consumer organizations almost phased out LAS in the late 1990s in favour of chemical alternatives.[27] The Swedish success was based on the use of ecolabelling, in particular the Nordic Swan label, established in 1989, and the Falcon, introduced in 1992 by the Swedish Society for Nature Conservation. Criteria for detergents were established in 1992 and included the requirement of biodegradability under anaerobic conditions, thereby excluding LAS in Swan labelled products.[28] The Swan label was effectively promoted in Sweden

and ecolabelled products achieved relatively high market shares. According to a study on the experience with the Swan, Swedish retail trade and professional purchasers played an important part in this process (Nordic Council of Ministers 2001a, p. 29, Nordic Council of Ministers 2001b, p. 45). The situation was thus different from the Danish situation, where the Swan was not adopted until 1998 because for some years the government gave priority to the EU Flower. The Swedish success has, however, turned out to be vulnerable: in 2003 the Swedish Society for Nature Conservation observed that LAS was reappearing through cut-price imports of detergents.[29]

Also, the issue of the reuse of sewage sludge as fertilizer has received attention in other countries. In general, EU waste policy favours the return of nutrients to the soil – an intention shared by the Danish and Swedish authorities (Danish EPA 1996; Swedish EPA 1995). However, it is highly contested when the sludge can be considered "safe", and farmers have been reluctant to trust assurances from the authorities. In Sweden, the reluctance turned into refusal when the dominant dairy group, Arla, introduced the restriction that their suppliers were not allowed to apply sewage sludge, and consequently, very little sewage sludge could be used in agriculture. After the merger of Arla and MD Foods, the dominant Danish dairy group, this restriction also applies to Danish suppliers.[30] In Switzerland, the two dominant food conglomerates have introduced the same restrictions, and the Swiss authorities have concluded that they could just as well ban the use of sewage sludge in agriculture.[31] LAS is not central to this conflict, but the conflict can influence the regulation of LAS in the longer term. If reuse is given up, regulation of LAS would be motivated by the impacts in the aquatic environment where business interests in minimizing LAS may not be so obvious.

4. Discussion of the Case

The following gives a thematically structured discussion of the case based on the three aspects that are considered central to the shaping of chemicals regulation. Simultaneously, the discussion highlights the lessons that can be drawn from the case regarding the effectiveness of different regulatory strategies.

The Understanding of Environmental Issues

The historical development of the LAS case shows that the prevailing understanding of environmental problems at a given point of time may present not only a possibility of identifying new risks and effects but also a limitation on what we can see. The 1975 ban on substances degradable to less than 90 % caused LAS to be recognized as an acceptable solution to the observed problems; however, that solution related exclusively to effects defined within current problem understandings. The approach of substituting with LAS did not anticipate the situation that new effects could arise, and nor did statutory regulation relate to the possibility that the use of surfactants in detergents and cleaning agents could involve more than just aesthetic problems.

In the debate during the 1990s, prevailing problem understandings proved a limitation with respect to the discussion on whether LAS should be regarded as harmful or not. This is because none of the criteria adopted for existing regulation encompassed the type of problems associated with LAS – including that LAS as an environmental problem presents no immediate threat to human health. The criteria on environmental harmfulness to a much larger degree were based on understandings related to hazards in the aquatic environment and aerobic degradation than to effects on soil and sediment and anaerobic degradation. Hence, the prevailing problem understandings could not serve as the basis for discussing harmfulness related to the reuse of waste, and regulatory intervention could not be justified with reference to existing standards and practice.

Moreover, the case of LAS regulation also demonstrates that new environmental concerns typically spring from new problem understandings. You cannot worry about what you do not know, which is precisely why few questioned whether the reuse of sewage sludge in agriculture was really an appropriate practice. The reuse of waste from humans and animals builds on a historical tradition reaching back to early cultures. Probably, the traditional and apparently natural character of the practice was one reason why the reuse of sewage sludge was not re-evaluated in the light of chemicals developed since World War II, which today have made sewage sludge a potentially harmful cocktail of chemical substances.

Pre-Existing Regulation

The LAS case shows that when all other options are exhausted, regulation tends to address the consumer. Due to the total harmonisation of EU chemicals regulation, the limited scope for national regulation lies in the national environmental acts. In the case of LAS, they have not resulted in regulation solving the problem; instead, regulation has created new problems, because recycling is a central regulatory principle of the existing system, which in turn has caused a dependency on using certain amounts of sludge as fertilizer. On a national basis, consumer-aimed regulation is an option, since it takes place on free market terms, and as such does not collide with EU chemicals policy and considerations regarding the free movement of goods.

The case also demonstrates that leaving the regulatory responsibility with the consumer is a dubious path since – in the case of LAS and other chemicals for which diverging perceptions of harmfulness exist – it is impossible to lay down unambiguous guidelines for an environmentally correct consumer choice. As the regulatory efficiency is influenced by consumers' lack of scientific insight and their subsequent sensitivity to stakeholders' influence, regulation may end up as the product of an arbitrary process. Given the complexity of the issues, the product-oriented strategy can be seen as political way to diffuse the responsibility, since such regulation fails to consider all the related problems as a whole, and because consumers and producers are made accountable for the regulatory efficiency.

However, as exemplified by the Swedish regulation, a product-oriented strategy may produce positive results, but the Swedish success relies on a close co-operation and consensus on the harm of LAS between authorities, retail trade, and environmentalist NGOs, and that these actors agree on the expediency of a LAS phase-out. Considering the Swiss ban of reuse of sewage sludge, it is worth noticing that industry is not always interested in hindering new regulation, but may be motivated to accelerate regulatory initiatives on issues upon which consensus about harmfulness has not yet been reached. Both the Swiss and the Swedish stories of reuse reflect that industry may be very vulnerable to potential or actual consumer demands (in this case the risk of consumers complaining about milk products 'tasting of waste' or containing dangerous substances).

In the case of LAS, the issue of xenobiotics and sewage sludge is placed on the political agenda due to the commercial interests of agriculture, thereby highlighting the point that commercial interests initiate and influence regulatory strategies. By tradition, Danish environmental law has given preferential treatment to the commercial interests of agriculture (Engberg 1999). In the LAS case, their interests are apparently given even higher priority than those of soap producers and the chemical industry. Admittedly, the setting of cut-off values for LAS in sewage sludge could be taken to imply that the regulation considers the interests of the industry, since not imposing a direct ban on the substance; however, the lower priority of industrial interests appears from the fact that Danish EPA adheres to its opinion of LAS as being harmful, regardless of the arguments and investigations of the industry. The EPA's consideration for the interests of Danish industry is apparent in relation to the producer-aimed subsidy scheme in which no requirements concerning environmental impacts or concerning the fulfilment of the Swan criteria are imposed as a precondition for supporting the development of new non-LAS products.[32]

The precautionary principle has proved to be a regulatory challenge rather than a straightforward solution. The implied interpretational task concerns the definition of a regulatory approach between two extremes: on the one hand (as today), permitting all chemicals, and on the other hand the utopian alternative of banning them all. Due to the diverging perceptions of LAS as harmful or not, this challenge manifests itself very clearly, since authorities and scientific experts take different positions. The existing LAS regulation is not based on an interpretation of the precautionary principle, which ideally would be a forward-looking regulation, ahead of as many effects and risks as possible, and involving all parts of the complicated issue. In the case of LAS, the Danish EPA's interpretation of the precautionary principle would appear to justify a political weakening of the responsibility – in some cases to such an extent that rational considerations behind the regulation are overshadowed by political interests, in terms of reassuring the public and displaying willingness to act.

The Organizational Set-Up of Contemporary Political Processes.

With the media being an actor, the LAS problem has been transformed from a matter of the environ-

ment to a matter of confidence, in a debate using LAS to exemplify the willingness and unwillingness, respectively, of authorities and industry to ensure the consumers' interests in environmentally friendly and safe products. The EPA's solitary approach vis-à-vis the industry is emphasized with particular reference to the precautionary principle and the regulatory concerns for humans and environment. The media actively distribute the roles, representing the industry's critical position towards the underlying rationale of the regulation as an attempt to "cheat" consumers, and not as a critique to be taken seriously, though actually supported by scientific experts in certain respects.

The absence of scientific experts in the LAS debate can be seen to express a tradition of objectivity, the cornerstone of our western approach to science. It may well be in the interest of experts to have a detached position in relation to a conflict between authorities and industry, because their trustworthiness is seen to depend on being apolitical. On the other hand, this form of objectivity can also be considered problematic, since the experts can leave the impression that they are just uncritical suppliers of whatever knowledge is in demand. Even more problematic is the lack of open discussion of different scientific perspectives and the uncertainties of results, because this lack contributes to maintaining the public expectation that it is possible to provide unambiguous descriptions of environmental problems and their solutions. Furthermore, the lack of openness enables other actors to design studies aimed to underpin whatever interests are at stake.

The focus on LAS as a single substance and on its presence in sewage sludge could indicate that the Danish EPA has a particular interest in maintaining a LAS regulation. The EPA does not request scientific investigations to clarify whether or not the industry's critique is justified, but upholds regulation, regardless of doubts. In addition, LAS is an obvious choice for a regulation, its presence in sewage sludge being easy to detect and chemical substitutes well known. Moreover, LAS phase-out involves no consequences that could evoke major animosity among consumers, since a substitution will not result in more expensive products or radical changes to laundering. However, since the experts are absent from the debate, the bias of the EPA does not become apparent. Instead, EPA initiatives gain support by the media, via their role distribution in favour of the authorities and environmentalist NGOs. LAS regulation provides an opportunity for them to display good intentions and provide confidence-building answers in a political field surrounded by increasing public attention and concern.

5. Recommendations Regarding Chemicals Regulation

Although the study discussed above only considers a specific case, we find that more general issues are illustrated and that it is possible to identify some of the future needs in relation to the development of the chemicals regulation. In the following we make some tentative suggestions, again organized according to the three aspects considered in the analysis of the shaping of the prevailing regulation.

Firstly, the present regulation is not designed to be abreast of future problems or to make sure that regulation is not generating new problems. There is a need for awareness raising as to the character of the problem understandings underlying our present approach to environmental and chemicals regulation, so we consider that given understandings can also imply blindness towards new problems. Increased awareness will enable a more proactive approach to new problems, reduce the risk of new problems emerging as a consequence of regulatory initiatives, and avoid over-focusing on particular problem understandings at the expense of others.

Secondly, regulatory measures are established far too slowly. A restructuring of the regulatory complex is necessary, opening up to a rather more forward-looking and holistic approach, including a substitution of the single-substance approach with e.g. group classification and approval of chemicals, based on structural similarities and computer modelling (cf. Bro-Rasmussen et al. 1996, where it is suggested that all substances in a group are classified as the most strictly classified substance in the group). In more concrete terms, we would suggest the development of a new listing principle, in which effects, risks and properties (instead of single substances) are recorded on a current basis. Such a list could provide the basis of a general and continuous analysis of prevailing understandings, and could also guide the choice of precautions to be taken, whenever new chemicals, technologies, and practices are introduced.

Thirdly, the present political processes imply that regulation tends to adopt an accidental character. There is a need for greater political accountability, including more attention to the role of the media in policy-making. In order to counterbalance research designed by stakeholders to support their specific interests, the state needs to take on the responsibility for supporting free and independent research. To ensure an optimal utilization of economic resources, steps should be taken to ensure that problems already subjected to considerable research activity are not further investigated at the expense of other issues. Existing scientific knowledge should be gathered and evaluated, based on independent criteria, and communicated to all actors to serve as a basis for public and scientific debate. Moreover, it is important for such research to be organized in an interdisciplinary way, since the study of environmental issues often involves knowledge from several branches of natural and social sciences. A narrow focus on chemical solutions (such as substitutions) may prove an inadequate approach, if the target is a general reduction of chemical impacts on health and environment. Potential solutions could profitably be sought in other scientific and technical approaches, offering solutions such as laundering processes without chemistry, e.g. applying ultrasound.[33] Moreover, such considerations could imply an appeal to industry towards adopting a broader approach to innovation, instead of staking it all on chemistry alone.

With the White Paper from 2001, the EU embarked on the process of improving the regulatory control of the many unregulated chemicals. The proposed new regulation of chemicals, REACH (Registration, Evaluation and Authorization of CHemicals), aims at regulating a large number of the substances introduced before 1981, that is, all chemicals produced or imported in quantities above 1 ton per year. To a large extent, the distinction between new and existing chemicals will thus be neutralized, and a part of the chemicals regarded as most harmful to human health will be subject to approval. REACH implies that the burden of proof will be moved from the state to the producers of chemicals and chemical products, and in addition, producers will meet more comprehensive demands for notification with respect to both hazards and exposure. REACH will have implications for the regulation of LAS as one of the chemicals introduced before 1981. LAS will be among the first chemicals to be subject to notification as the substance is among the high-volume chemicals produced in more than 1000 t per producer per year. It is positive that scientific knowledge of this intensively tested substance will finally be gathered, but it is hard to predict how REACH will affect the regulation of LAS with respect to the risk assesment and hazard classification, since the final form of REACH is far from agreed upon.

Compared to our recommendations regarding future regulation, REACH can, in some ways, be expected to respond to our concerns. We find it positive that the regulatory approach will be restructured by moving the burden of proof, making the existing chemicals subject to regulation, taking into account the diversity of exposure on several levels of production and, partly, implementing the idea of group classification. The focus on different exposure paths may present a possibility of being abreast of future problems and of increasing the awareness of new problem understandings. However, the optimistic expectations are shaken by the character of the political processes that are transforming the intentions of the White Paper. The chemical industry has been quite successful in lobbying against the proposal, which has been watered down in many respects. At the time of writing, it still remains to be seen what the reform will achieve.

6. An Ecological Modernization Perspective

Whereas the section above concentrates on recommendations regarding regulatory change, the intention with this section is to discuss briefly some theoretical implications of our study in relation to the discourse on ecological modernization. First a few words on the concept.

The concept of ecological modernization came into widespread use in the late 1980s and early 1990s when a relatively optimistic view of environmental policy achievements prevailed. Several authors introduced and used this and other terms (e.g. "the new politics of pollution") to characterize a new era in environmental politics, in which the dominant perception of an inherent conflict between economic prosperity and environmental improvement gradually gave way to endorsement of the view that economic growth and environmental improvement could be obtained simultaneously. New environ-

mental policy instruments were introduced, initially mostly as theoretical regulatory options and later increasingly as applied instruments, such as economic incentives, voluntary agreements, labelling, public procurement, promotion of environmental management systems, etc. It was assumed that instruments based on self-regulation and mutual regulation in networks would be adequate, since progressive firms had come to realize the necessity of concerted environmental action. In the same period, however, there was also a marked trend towards deregulation, unburdening industry of irksome regulations, and from this perspective, the very same instruments could be interpreted as a way of renouncing environmental ambitions.

More recently, the general attitude towards the ecological modernization process has become more sceptical. For one thing, this scepticism arises from an increased focus on global environmental problems and the related distributional problems. Although national environmental regulation has proved successful in several sectors, answers to more serious problems related to climate change, biodiversity, disruption of ecosystems etc. are making only slow, if any, progress. In the words of Langhelle (2000), ecological modernization should be seen as a necessary, yet not necessarily sufficient, strategy towards sustainable development. Gradual improvement through environmental management may not suffice, so more structural changes in production and consumption patterns may be needed, requiring intensified political intervention (Andersen and Massa 2000).

In general, the debate on ecological modernization has referred primarily to developments in environmental regulation, while the evolution of chemicals regulation has been addressed to a lesser extent. The debate has included very important work on the chemicals industry, in particular Mol (1995, 1997), but such studies have been relatively seldom, and the issues related to the large number of unregulated chemicals have not received much attention. In the wake of the Bhopal-disaster and elaboration of the Seveso Directive, production processes in the chemicals industry have presumably been developed towards greater safety, so a focus on production tends to inspire a relatively optimistic evaluation of policy achievements with regard to the environmental impacts of chemicals. However, a more product-oriented perspective, as in the LAS case, contains arguments for a more pessimistic evaluation. The case demonstrates that even dealing with a single substance is an extremely complicated process, that contingencies and lack of political accountability influence regulation, and that our present chemicals regulation falls sorely short of handling obvious and well-known challenges.

Along with this more pessimistic evaluation of the regulation, we would like to add two specific comments on the theories of ecological modernization. First, the increased use of market-based instruments has been represented as progress in environmental policy: this regulatory strategy allegedly allows national authorities to limit themselves to setting market conditions (by instruments such as taxation, certification, and labelling schemes), which – through increased competition combined with raised environmental awareness among companies and consumers – would motivate environmental progress. However, the case of LAS demonstrates that such regulatory instruments are occasionally of questionable value. Environmental problems may be too complex for such an approach to produce actual environmental progress, and there is a risk that the regulatory efforts aim more at inspiring confidence than at achieving environmental improvements. As Andersen and Massa (2000), we believe that national authorities need to undertake more responsibility through direct regulation of the more serious environmental problems. In particular, it is important that consumers are not left with the responsibility for the regulation of problems, the seriousness of which other actors with greater expertise cannot even agree upon. Nor should producers or other actors with vested interests be allowed to control the development in areas involving considerable uncertainty. We thus propose a more binding intervention by national authorities and political processes evolving at a greater distance from media-based symbol politics, contingencies and lobbyism by economic players (Bro-Rasmussen 2002).

Second, in the ecological modernization debate, there is often a fair amount of confidence that scientific experts are able to identify environmental problems and suggest viable solutions. This confidence often leads to the conclusion that the environmental problems are increasingly under control. However, the collection, interpretation and use of scientific

knowledge are necessarily limited by the fact that environmental problems are considered based on prevailing understandings – and that these evolve exceedingly slowly, based on lessons learned, when the harm *has already been* done (European Environment Agency 2001). The limits to scientific knowledge have especially been emphasized by researchers in social studies of science (SSS), and in our opinion, the future development of the ecological modernization perspective could benefit from drawing upon such insights – although we, as Mol and Spaargaren (2000, p 28-29), dissociate ourselves from the more extreme versions of post-modern deconstructivism. In the more applications-oriented parts of the SSS literature (Yearley 1997; Cortner 2000), we find interesting discussions of the expert role in politics, much in line with the lessons that can be drawn from studying chemicals regulation. Our case thus suggests that increased responsibility in the chemicals regulation will necessarily require actors to understand and accept the limitations related to collection, interpretation, and application of scientific knowledge. Such an approach would imply a break with the familiar expert role, and a redefined role distribution between science and the political system, involving far more dialogue between the expert and society. Moreover, the notion of objectivity must be "dismissed", along with greater appreciation of qualitative answers as opposed to quantitative answers. Such transformations will prove a challenge to politicians and professionals, and last but not least, to the scientific experts, who will have to break away from their tradition of objectivity – a mainstay of western science, of which they themselves are a product.

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Notes

1 Rendering the findings of Brickmann et al. (1985) would take us too far; however, it is worth noting that this study is akin to the comparative study of Lundqvist (1980) on environmental regulation in the US and Sweden.

2 Bro-Rasmussen, F., Department of Manufacturing Engineering and Management, Technical University of Denmark. 2002. Personal communication.

3 To illustrate the point, we should mention that nine hazard symbols refer to health hazards and danger of fire or explosion, while just one symbol refers to environmental hazard.

4 Kusk, K.O., Environment & Resources, Technical University of Denmark. 2002. Personal communication.

5 Holten-Andersen, J., The Danish Nature Council. 2002. Personal communication.

6 In the present context, 'product' denotes compounds of pure chemicals, and not consumer goods. It is characteristic of the established regulation that chemicals used in consumer goods are yet to become subject to consistent regulation.

7 A more detailed introduction to the harmonisation concept is given by e.g. Dahl 1997, Højbjerg og Marscher, 1995.

8 Approved (also called positive lists) lists are listings of approved pesticides and additives in cosmetics and foodstuffs, respectively. The practical implications of such lists is that chemicals other than those listed are disallowed for those applications. The list of hazardous substances is a black list (also called a negative list), comprising all chemicals under regulation. In practical terms, blacklisting implies that all non-listed chemicals are permitted. Moreover, until now, substances marketed before 1981 have been exempted from mandatory investigation and reporting (Bro-Rasmussen et al. 1996).

9 The regulation includes a demand for self-classification, but characteristically does not specify the investigations, upon which such self-classification should rely. As a result, it is possible for identical chemicals to be classified differently by their manufacturers.

10 www.mst.dk, "Status og perspektiver på kemikalieområdet" (1996).

11 The designation LAS includes a number of homologous and isomeric chemicals that are structurally similar but vary slightly in size. In this work, LAS is treated as one substance, since regulation does not distinguish between different molecules.

12 The Association of Danish Cosmetics, Toiletries, Soap and Detergent Industries (SPT), 2002.

13 Kusk, K.O., Environment & Resources, Technical University of Denmark. 2002. Personal communication.

14 During the 1980s, the ban was harmonized among EU members, and the content of the Detergent Directive is no longer a national matter.

15 Nyholm, N., Environment & Resources, Technical University of Denmark. 2002. Personal communication.

16 The three groups of xenobiotic substances besides LAS were: Nonylphenoles (NPE), Phthalates (DEHP) and some Polyaromatic hydrocarbons (PAH).

17 In 1996, cut-off values were set at 2600 mg/g DM and lowered to 1300 mg/g DM in 2000.

18 The Danish List of Undesirable Substances exemplifies a Danish attempt to press for a more progressive EU chemicals policy, cf. Dahl (1997).

19 The diverging perceptions are possible due to certain degrees of freedom associated with the testing of effects and the choice of substitutes. In the case of LAS, one of the challenges concerns the creation of realistic conditions in the laboratory. The outcome of, e.g., biodegradability tests is dependent on the degree of adaption to the degradation of LAS of the chosen bacteria and on physical-chemical parameters such as the temperature. In real life these conditions will vary, e.g., between different sewage treatment plants and between seasons, but in the laboratory conditions may be chosen so that optimal results are achieved. Substitution is not a straightforward solution as the knowledge of risk and effects associated with substitutes for LAS may be less investigated than LAS itself, and unexpected problems may emerge when the substances are used.

20 It is worth noting that this argument does not attach any particular importance to the harmful effects of detergents observed in aquatic organisms.

21 The designation "scientific experts" refers to the scientific staff of public and independent research institutions and not to scientifically educated staff employed by industry.

22 Kusk, K.O., Environment & Resources, Technical University of Denmark, 2002. Madsen, T., DHI Water & Environment, 2002. Nyholm, N., Environment & Resources, Technical University of Denmark, 2002. Personal communication.

23 Kusk, K.O., Environment & Resources, Technical University of Denmark. 2002. Madsen, T. DHI Water & Environment. 2002. Personal communication.

24 According to Toräng, L. and Kusk, K.O., Environment & Resources, Technical University of Denmark, 2002, personal communication, xenobiotics in waste water and sewage sludge is not a field of research having a high priority for the Danish authorities. The complexity of this field is caused by the huge number of substances and of degradability products which, in interaction, may imply a variety of effects.

25 By 2002, the EU Detergent Directive was yet to specify requirements on anaerobic degradability. However, the Danish EPA tried to influence the directive towards adoption of such requirements.

26 Our treatment of the Swedish regulation serves to exemplify how actors and actor alliances may influence the development of a regulation. We do not deal with the relation between the Swedish regulation and the scepticism amongst Danish experts with regard to chemical alternatives.

27 The Swedish substitution has been in favour of anionic surfactants lacking an aromatic part. See Kemikalie-inspektionen, http.//apps.kemi.se/flodessok/floden/kemamne_Eng/LAS_eng.htm.

28 See http://www.ecolabel.dk/NR/rdonlyres/B669C92F-DD11-407C-B08C-7A6296E11E3B/0/SvanenTekstilvaskemidler.pdf.

29 See http://www.snf.se/pdf/bmv/dok-hmv-lasfakta.pdf .

30 See http://www.arlafoods.dk/C1256FB900349710/O/7663A3A5CFDF9C55C1256FBA00317CDE.

31 Werther, I. Danish EPA, Department of Soil & Waste. 2006. Jepsen, S.E,. Confederation of Danish Industries. 2006. Personal communication.

32 Møller, L. Danish EPA, Department of Chemicals. 2002. Personal communication.

33 See for instance: www.designnews.com/index.asp?layout=articleID=CA201955. These techniques may imply other environmental problems, but we just want to emphasize the possibility of increasing the understanding of laundrying and thereby the possibility of exploring new solutions.

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