Hazardous Chemicals Can Be Substituted

The Ecological Council

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Preface

Among production managers and industrial engineers a certain hesitation towards engagement in tasks of substitution may often be noted. Presently operating processes are found to be optimised and well known to them, and generally it is the feeling that the handling of dangerous chemicals are under control. Contrary to this situation, most often there is a feeling of insecurity when the application of alternative, less hazardous chemicals are presented as options, not to mention the insecurity if confronted with totally new processes and products.

Substitution of hazardous chemicals, however, is undoubtedly one of the most important tools by which the chemical impact on humans as well as the environment may be reduced resulting in a reduction of the damaging effects, which can be caused by chemicals. It is important, therefore, that the concept and practice of substitution is introduced into the training and education programmes for production managers and practitioners in their future engineering tasks and thereby made into an integrated part of their frame of understanding.

Substitution is to some extent embedded in present chemical legislation, and a range of tools, which are useful for the practice of substitution, already exists. One thing, however, is theory and another practice, and barriers as well as challenges are plentiful when substitution is to be introduced. This book is written and presented to deal with such questions. It presents both theoretical overviews and several examples of already developed substitutions in order to illustrate not only the challenges, but also some ways and means, which may be utilised for meeting the challenges. It may therefore become an excellent starting point for an introduction of the substitution concept to an academic and technical audience at university level.

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Introduction 1.

During the 20th century we have seen a massive increase in the use of chemical substances. When we talk about chemical substances, we refer to industrial chemicals that are industrially manufactured, isolated or concentrated in a form not originally found in nature[1]. The total global production of chemicals has grown from one million tonnes pr. year in 1930 to 500 million tonnes pr. year in 2005. The reason for this growth is that many modern products such as computers, technical equipment in general and plastic products all contain industrial chemicals. And these are all products, which did not exist 80 – 90 years ago. Similarly, today's cosmetic products, textiles and children's toys often consist of or contain several industrial chemicals. We say that a chemical revolution has taken place. Many of the industrial chemicals were introduced into the market before they had been tested to determine possible unwanted effects. And therefore it has not been possible to predict which long-term negative consequences these chemicals may have. Some chemicals may, for instance, affect both humans and animals by disturbing.hormonal processes and/or systems.

Although today we know much more about industrial chemicals, we still have a long way to go. For example, we need to find out more on how this growing production of chemicals affects humans and the environment. No one knows exactly how many different chemicals are on the market at the moment or which properties these chemicals have. Around 100,000 chemicals are registered as being marketed within the EU, of which approximately 30,000 – 50,000 are currently estimated to be marketed on a regular basis. And of these, from 5,000 - 7,000 are classified according to EU regulation. The rest of them are either harmless or they have not yet been assessed at all[2]. The Danish EPA has by means of socalled QSAR computer models assessed thousands of chemicals. Using this computer screening methodology, the structural features of the chemicals can be determined, and based on that information it has been possible to predict the effects of chemicals on human health and the environment. The Agency thereby assessed 46,000 chemicals out of which 21,000 were found to have hazardous properties according to EU standards. This indicates that there are a much greater number of dangerous chemicals on the market than the 7,000 already classified.

In many ways, the development of industrial chemicals has contributed to the increase in wealth in the Western part of the world. But at the same time, the

1 Essentially, everything is made up of chemicals - including animals and plants. But here we are thinking of chemicals which are industrially manufactured. Examples of manufactured chemicals are: synthetic chemicals, substances that are extracted from natural resources or substances concentrated to a form not found in nature (such as heavy metals).

2 Project No. 843 2003, An outline of environmental regulations focusing on health aspects, Danish EPA.

same chemicals have caused massive environmental and health problems. Some of the industrial chemicals may cause infertility, cancer, allergies and/or genetic changes, or they may affect fragile ecosystems as well as wild animals. We are surrounded by industrial chemicals, which often end up in consumer products, in humans and in the environment. Eventually, at all stages of their life cycles, the chemicals will leave traces that may pollute the environment. Even though some chemicals only exist in small amounts, they may still be a problem as they can accumulate and possibly concentrate up through the natural food chains. Most of us carry many chemicals in our bodies, and some of them have – even in small doses – a negative impact on human health.

When scientific test results show that a certain chemical is hazardous, it will often take years before the EU bans the chemical or decides to regulate its use. The reason for this is that there is no agreement as to how much evidence is needed in order to ban chemicals. Is it enough to do tests on tissues or bacteriae? Is there a need for animal testing? Or must it be proved that the substance is harmful to human beings? The way it is today, it is not enough to suspect that a chemical substance is hazardous. Test results must indicate with a high degree of probability that the substance is harmful before it will be regulated. The current legislation on chemicals has simply been outdated by the rapid growth of chemical industry, including the heavy marketing of chemical substances and products. Therefore, it is important to gain more knowledge on the hazardous chemicals and the impacts of these on humans and the environment in order to reduce their use and/or to replace them with non-hazardous – or at least less harmful – alternatives.[3]

In this book, we will give examples of companies that have successfully substituted dangerous chemicals with harmless or less hazardous alternatives. There will be given examples on the challenges and presented experiences, which have been gained by companies during their substitution processes, and there will be descriptions on the effects that the substitutions have had on the environment. But first, we will determine what substitution is.

3 See European Environmental Bureau's web site: www.eeb.org

3. What is Substitution and Why Substitute?

Why is substitution such a good idea? The answer is: We are all surrounded by thousands of chemical substances, of which some are suspected or known to have hazardous effects on the environment and on human health. The best solution to this problem is to substitute the hazardous chemicals with some less hazardous ones. The substitution will then help improve the environment as well as the working environment. In fact, according to the working environment legislation, companies in Denmark are required to substitute[4]. In case dangerous chemical substances are substituted in consumer products, this may lead to an improved protection also of consumers. However, it is important to have adequate data on the hazardous effects of both the original chemical substance and its substitute. In Denmark, we have seen several successful substitution projects. And even though it sometimes at first sight has looked as if the end products would turn out to be more expensive and of poorer quality after a substitution has taken place, advanced technology has in the end made it possible to produce competitive products.

Substitution is a way of addressing the core issues. Instead of using dangerous chemicals or finding ways to prevent them from coming into direct contact with humans or fragile eco-systems, the industry may either substitute the hazardous chemicals with less hazardous substances or the production processes may be changed. Our history is full of examples, which show how difficult or almost impossible it can be to encapsulate dangerous substances and therewith prevent them from coming into contact with the environment or humans. The ancient Romans' used lead water pipes, but they did not know that lead could dissolve into the drinking water. Lead water pipes are in fact still used in the UK. Similarly, it was believed for many years that it was completely free of health risks to use asbestos in building materials, because no asbestos fibres were released into the air. But it was later discovered that it is close to impossible to sustain such conditions that asbestos is not released. The asbestos containing materials are dissolved as a consequence of damp damages or by mechanical wear. And sometimes when old houses are renovated, builders accidentally cut into asbestos materials. Problems also occur during building demolitions[5]. During the 1980s, it became increasingly clear that a practice of

4 Executive order 292 of April 26, 2001 on Work with Substances and Materials
5 Søren Kudahl, Ugebladet A4 (A4 Weekly), 11.4.05

protecting the building workers from hazardous materials by providing them with highly protective clothing was insufficient. No one is capable of working long stretches 'dressed' in uncomfortable clothing, and often the workers neglected to wear them and work related injuries would occur[6].

Another example is that the current EU legislation on heavy metals (such as lead and cadmium) in children's toys only focuses on the release of those metals from the toys. Producers of children's toys are not allowed to market products that release metals when they come into contact with saliva or stomach acid. Thus toys can contain heavy metals as long as these are not released during product tests. However, the legislation does not cover situations where metal dust is released into the air after mechanical wear of some toys. Nor does it take in to consideration that metals are released from the toys when they are burned or left at the landfill.[7] To a certain extent, it would be possible to set up separate disposal facilities for toxic waste materials and to have these treated at a special waste treatment plant, in Denmark called Kommunekemi (Municipal Chemistry). However, it is not possible to extract heavy metals from regular consumer products in order to make certain that the rest is treated as ordinary waste.

Substitution can simply be a replacement of a certain substance or a process with another substance – such as vegetable oil as an alternative to benzine, but often the substitution requires more changes. In paint products containing organic solvent, it is not enough simply to replace the solvent with water. It may also be necessary to replace the binding agents as well as several other constituents. In such cases, focus has to be shifted from the product itself and, alternatively, to concentrate on its function. For instance, marine paint, which are made toxic to marine life and used in order to prevent mussels etc. from attempting to attach to the painted surfaces, can be replaced by an environmentally friendly, non-sticky coating which gives the hull a smooth surface on to which mussels cannot attach. Or, the toxic marine paint may be replaced by frequent mechanical treatments or by a combination of the two alternatives.

Likewise, aggressive cleaning products can be replaced by products more environmentally friendly – or by micro-fibre cleaning cloths, which would represent a more radical substitution. Wood coatings containing biocides are known to have negative effects on the environment, but it is not possible to simply replace them with less hazardous products. However, in many cases using more resistant types of wood could solve the problems. Another solution could be constructive wood protection – that is, constructing houses etc. in ways which limit the wood's exposure to severe weather conditions.[8]

When companies decide to substitute, it is important that they make sure that the substituting substance(s) or the new production method are in fact better for the environment and for human health. This means that it is important to know the exact chemical composition of their products. But often the producers of the raw materials are reluctant to supply this information, which makes

6 Hansson & Hellsten: Arbejdsmiljø fra A til Ø (Working Environment from A to Z), Forlaget Fremad, 1999
7 Danish Environment Protection Agency: Måling af farlige stoffer i legetøj (Chemicals, Environment and health), Miljøprojekt 1984
8 Danish Environment Protection Agency: Tips om træ og træbeskyttelse (Guide on wood and wood protection) på www.mst.dk

it almost impossible for downstream users to minimise the negative effects on the environment and on human health. A radical EU chemicals reform will be helpful in this case, as it can force producers of raw materials to supply information on the chemical compositions of their products (see later section).

The next question is whether the decision to substitute ought to be made on the basis of a risk assessment or on a hazard assessment. A hazard assessment only examines the dangerous features of the chemical substance itself – the so-called inherent properties of individual chemicals. A risk assessment, on the other hand, also takes into account: the quantities of the chemicals, the potential release and distribution into the environment and the risks of accumulation in humans, animals or plants. Hence, risk assessments are very complicated; they take a long time to complete and they involve great insecurities of both technical and societal nature.[9] As previously mentioned, there are numerous cases in which producers did not give any considerations to the potential risks for the environment before launching their products into the market. If a decision to substitute is based on a hazard assessment, the decision may be taken at a relatively early stage and with greater precaution, enabling that hazardous chemical substances can be phased out simply because they in themselves are known to have dangerous features.

Hazard and risk assessment

A hazard assessment seeks to outline the inherent characteristics of chemicals – that is, characteristics that the chemicals have, regardless of its quantity, way of production, use and discharge. So, the assessment is made by comparing physical-chemical data, degradability, accumulation capacity, eco-toxicological and toxicological data.

The aim of a risk assessment is to describe and assess the health and environmental risks connected with a given chemical substance. The assessment is done by comparing the potentially harmful effects (the hazard assessment) of the chemical with the expected quantities to which humans and the environment can be exposed.

A thorough risk assessment is severely time consuming and often there are many uncertainties associated with this activity[10].

Therefore, if the hazard assessment shows, that a substance potentially can be very hazardous, there can be a good reason to react on this, in stead of waiting for a full risk assessment.

Based on this information, it is no wonder that opinions and interpretations concerned with regulation on chemicals are widely differing. The opinion of the majority of the chemicals producers seem to be that there should be no regulations on any chemicals before they have undergone the full risk assessment, as this might delay a regulation on hazardous chemicals. In contrast, many environmental organisations believe that there ought to be regulations on chemicals based on a hazard assessment. On the other hand, it is not meaningful to simply ban all hazardous chemicals, as many of these serve valuable purposes.

In some cases, the dangerous chemicals can have positive effects of value for the society as well as the environment. For example, mercury contained in low energy lights bulbs (see below), are acceptable as long as we do not have a better alternative. In the meantime, however, it is important to encapsulate the dangerous substances, to re-cycle properly and to remove waste products responsibly.

9 The Ecological Council: Kemikalier, miljø og sundhed (Chemicals, environment and health), 2003

10 For further information see ECB's web-site: www.ecb.jrc.it

2.1 Substitutions and Life-cycle Assessment

In order to prevent substitutions of a hazardous chemical substance from causing harm to the environment, it is important to look into its entire life cycle – this means, examining the effects of the substance on the environment during the production of raw material, the actual manufacturing process, its use and during the waste disposal. These examinations are complicated, similar to our frequent comparing 'apples to oranges'. For instance, significance of the energy consumption with its release of greenhouse gasses, sulphurdioxide etc. may have to be measured against the use and release of environmentally hazardous substances. In this connection, the question have been raised of whether the environment really is protected better when low energy light bulbs are used instead of classic light bulbs. Low energy light bulbs use less energy but, in turn, they may contain a small amount of mercury. From a Danish perspective, however, the question is easy to answer, as a major part of the energy production in Denmark is based on coal. And since coal contain mercury; this will be released during the combustion. The reduced use of energy – via a reduced expenditure of coal – will result in less release of mercury, even after the amount of mercury in low energy bulbs has been deducted.

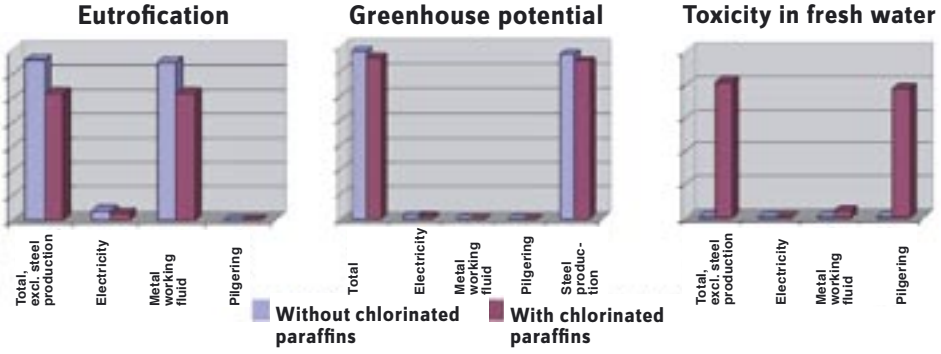


Figure 1
Comparison of environmental effects of coolant with and without chlorinated paraffins.[12]

Moreover, the advantages connected to a reduced release of CO_2 etc must be added. Thus, a life cycle assessment will clearly indicate that low energy light bulbs are better for the environment.[11]

Similarly, the ECB[13] has, as part of a major EU project on hazardous chemical substances[14] and in co-operation with Institute for Production and Management at The Technical University of Denmark (IPL/DTU), examined coolants with and without the harmful chlorinated paraffins (MCCP). It was found that the products without MCCP were less effective, which then resulted in an increase in

11 ECO labelling of light sources, Birgitte Holm Christensen, Miljømærkesekretariatet (Danish Ecolabelling secretariat), www.ecolabel.dk

12 Hansen, MS, Olsen SI, Vanthournout H and Christensen FM: Comparative Life Cycle Assessment of metal working fluids with and without Medium Chain Chlorinated Paraffins. Contribution to Work-package 5 as appropriate deliverable D37 of the OMNIITOX Project. January 2005. EC Project contract G1RD-CT-2001-00501

13 ECB: European Chemicals Bureau – a subdivision of the EU Commission

14 OMNIITOX, www.omniitox.net

energy and steel expenditure, and, consequently, also an increase in damages to the environment. Figure 1 depicts a comparison between two types of coolants. It is shown that the degree of toxicity affecting organisms living in freshwater is many times higher when MCCP is added, whereas the release of green house gasses and the eutrofication (discharge of nutrient salts and organic materials leading to algae growth and oxygen reduction) are marginally lower compared to the alternative. It was found that, on the whole, the coolant without paraffins is the least hazardous to the environment. Furthermore, if the examination had covered issues concerning the working environment, the result would have been the same. This example also highlights one of the major problems related to life cycle assessments, namely the lack of data on the alternative and the problem, in general, of collecting data on production of chemicals.

3. Danish and EU Legislations on Chemicals

In Denmark, the import, sale and use of chemical substances are regulated according to the Law on chemical substances and products. The chemicals legislation covers pure substances such as acetone and nitric acid. It also covers preparations such as cleaning products, paint and lacquers, shampoo and computers. The regulation of chemicals is an area of so-called total harmonisation. This means that all member states must follow EU directives. Denmark has, however, a few more strict national rules on the area.[15]

Some substances are fully banned according to EU legislation – for example PCB and CFCs – while some other substances can only be used restrictively. It is, for example, illegal to use three of the most hazardous so-called brominated flame-retardants in electronic equipment. Additionally, a few other substances are illegal according to national Danish legislation. Lead and mercury are both – with a few exceptions – withdrawn from the Danish market. Besides, private consumers cannot buy substances classified as poisonous. In cases like these, producers are forced to substitute. The Environmental Protection Agency has published a List of Unwanted Substances. The substances on this list are not banned. However, the list recommends and encourages substitution as a practice and it is aimed at producers and importers of chemical substances, and can therefore be read as a precursor to future regulations.

Contained in the Danish Working Environment act, is a demand for hazardous chemical substances and materials to be substituted in the workplaces whenever possible.

The employer is under obligation to cooperate with the company's safety organisation whenever potential substitutions are considered. If a less hazardous substance or working process exists, this must replace the old substance or process. The regulation covers all product types, including paint products, epoxy glue, cleaning products etc.

The employer must ensure that hazardous substances and materials in the workplace are removed, replaced or reduced to a minimum.

Measure must be taken to replace a hazardous substance or material with one non-hazardous, less hazardous or by a less irritating substance or material in the working processes. If a replacement is not possible, this must be documented at the Working Environment Authority's request.

A replacement must be carried out even if the effects of the hazardous substances are insignificant.

If the use of an alternative substance involves considerable negative changes in technical features or costs, then this must be balanced against the health and safety impacts. If a replacement cannot be performed according to subsection 1 or it is omitted because it has been determined after weighing - according to subsection 2 - that a substitution to another substance or product would entail unreasonable increases in cost, then must be documented at the Working Environment Authority's request.

The company's safety organisation must be included in the assessment of whether a substitution can be made.

Executive order of the Danish Working Environment Administration (WEA), on substances and materials in the workplace no. 292 of 26.4.2001

15 For more information on the Danish legislation on chemicals, see the Danish Environmental Protection Agency, www.mst.dk

If the WEA, after a visit to a factory, note that the company has not considered substitution of a dangerous chemical, the company will be ordered to stop using that specific substance in their production. Under these circumstances, the problem is handled as a serious health and safety problem, and the company may therefore be ordered to seek assistance from an authorised environmental consultant. In reality, this means that the company must contact 2-3 new suppliers in order to find out if a safer alternative is on the market. If such an alternative exists and it meets the technical and economic requirements, it must replace the old substance. In case the company finds that the alternatives must be rejected because of 'unreasonable extra costs' or because of inadequate technical features, they are obliged to provide the WEA with written documentation. The final decision of whether or not it is feasible to perform the substitution will be based on estimate. But if other companies already have performed the same substitution, it makes sense to suggest that all other similar companies do the same.[16]

As already mentioned , the regulation includes a balance against technical and economic considerations. This may cause problems, especially where there have been no previous cases of the same kind. Conversely, if other companies already have substituted a certain chemical substance, all producers of similar products will be ordered to do the same. Furthermore, it has been decided that companies can be ordered to seek external environmental expertise to help solve their working environmental issues, including substitution.[17]

3.1 REACH and Substitution

The current EU legislation on chemicals is inadequate when it comes to protecting human beings and the environment against hazardous chemical substances. Legislation enacted in 1981 requires new chemicals to be tested before they are introduced into the market, whereas more than 100.000 chemicals already on the market in 1981 were not subject to the same requirements. Then in 1993, it was decided that selected existing substances should be tested and assessed. 141 substances of high concern were selected. However, the specific test requirements were so extensive that until now only 70 of those chemicals have been assessed. The results showed that 57 of these 70 chemicals needed to be regulated. So far, this has only happened in 11 cases[18]. Hence the demand for risk assessment has had a negative effect, which has almost stopped the whole EU process of regulation in terms of banning or limiting the marketing of hazardous chemicals.

Table 1
The amount of health and environment data for high volume substances, i.e. produced in quantities above 1,000 t/producer/year.

Table 1

Adequate data	14%
Partly adequate data	65%
No data	21%

Table 1 indicates that out of those 3,000 chemicals, which are produced and used in largest amounts, i.e. in quantites above 1,000 t/producer/year, and which

16 For more information on the Working Environment Act, see www.at.dk
17 Information given by Peter Herskind, head of division, the Danish Working Environment Authority
18 http://ecb.jrc.it/NewsLetter/newsletter200503.pdf

therefore could be expected to be well documented, only about 14% are adequately tested for possible hazardous properties.[19]

The concept and need for a new EU legislation on chemicals was effectively introduced at the Environment Council in Chester, April 1998. Here, the Commission promised to launch a review of the ineffective EU legislation on chemicals, and consequently in 2001 a White Paper was produced under the title: Strategy for Future Chemicals Policy. This paper suggests that both new and existing chemicals should be subject to the same regulatory framework: the REACH system.[20]

REACH [21]

Registration
Manufactures and importers of chemicals are required to register chemicals manufactured in quantities above 1 tonne with the European Chemicals Agency. The manufactures and importers are required to supply the Chemicals Agency with data on the impacts of the use of the chemicals before they are allowed to register them. The data demands vary according to the size of the production.

Evaluation
The Chemicals Agency will together with the member states evaluate the data and determine the impacts of the chemicals on human health and the environment.

Authorisation
An authorisation is required each time hazardous substances like CMRs, PBTs, vPvBs and similar hazardous chemicals are used.

Chemicals
The term covers chemical substances and mixtures of these (preparations).

REACH is intended to promote substitution by means of the authorisation demand. The new data available on the existing chemicals will also have a direct effect on future substitution projects, in so far as producers and companies will have better and more in-depth knowledge of environmental and health effects of the substances, thereby providing them with important tools for substitution.

Immidiately following the publication of the White Paper, many organisations began to lobby the EU on REACH. In October 2003, the Commission proposed a new regulation, which is presently being negotiated by the European Parliament and the Council. The Parliament ended its first reading in November and the Council in December 2005. According to the Commission the law will come into force in 2007.

The Commission's regulation proposal for regulation – by the end of October 2003 – is more slack than the White Paper regarding scope, safety demands and information. One of its weak points is that the existence of a safer alternative is not considered sufficient to secure a dismissal of a dangerous substance – in other words a weakening of the substitution principle.[22]

Since the proposal of 2003, members of the Parliament have proposed many amendments which the Parliament voted on in November 2005. The Council reached their decision on December 13, 2005. A second reading is expected to be held in 2006. Therefore, no one knows what the final REACH regulation will

19 Allenou et al.: Public available data on EU high production volume chemicals, European Chemicals Bureau, 1999
20 REACH eller kaos (REACH or chemicals chaos), Danish Society for nature Conservation, 2005
21 Read more on REACH on ChemSec: www.chemsec.org
22 See www.mst.dk

hold[23]. Denmark, along with other countries, has advocated that a substitution principle should be developed and be laid out for substances regulated as part of the authorisation request. Further, Denmark prefers that the new law on chemicals shall reflect the substitution principle in such way that hazardous chemical substances can be substituted on the basis of health and environmental risks, taking into account also technical and economic practicabilities. This substitution principle was included in the White Paper's description of a strategy for future chemicals policy, and it is an essential part of Denmark's national strategy for sustainable development.[24]

23 Stay updated on the latest new on REACH in the newsletter REACH-info, www.reachinfo.dk (in Danish)
24 For more information on Denmark's standpoints, see www.mst.dk

4. Promoting Substitutions: Tools and Means

There exist a number of tools and means for promoting substitutions of chemicals. Some of these will be presented in this chapter.

4.1 Tools for Promoting Substitutions

In 2003 The European Agency for Safety and Health at Work, The Danish Working Environment Authority and The Danish Ministry of the Environment launched the web site: www.catsub.dk. The site is produced by two BST Centres (consultancies in working environment), and it contains more than 200 examples of substitutions, all gathered from different companies as well as from the BST Centres, the Environment Agency and the Working Environment Agency. The site sets out that substances less harmful can replace the following hazardous chemicals:

- Strong solvents used to clean and glue plastic- and metal objects
- Greenhouse gasses used as refrigerants
- Metal working fluids which may result in skin irritation and allergies
- Chlorine-containing bleaching agents used on textiles

Figure 2
On www.catsub.dk you will find more than 200 examples of substitutions of dangerous industrial chemicals.

Some industrial and commercial associations are trying to find ways for their members to identify hazardous chemicals in their productions. This identification is, of course, the first step towards an actual substitution. The Ministry of the Environment supported a project, which was carried out by the paint-, glue- & lacquers industries. The purpose of the project was to teach and initiate members of the association on how to fulfil the coming new legislation on chemicals. Furthermore, the industry did, as part of this project, contribute to the development of new ways for the members to deal with the new legislation. The project also gave them more knowledge about the different chemicals and about how to develop less harmful substances. The paint- & lacquers industry has during the past 25- 30 years already undergone an extensive substitution process where organic solvents have been substituted for water-based solvents. This project was carried out after several cases of brain damages, which were discovered in the 1970s and 1980s among painters who had continuously been exposed to organic solvents. Similarly, the industry has replaced the hazardous solvent Dichloromethane found in paint removers. They chose[25] to replace Dichloromethane even though the substituting substances worked less effective.

25 In fact, they were forced to substitute because it appeared on the executive order on cancer

Many products must be labelled with a so-called MAL-code. This goes for paint products, glue, joint fillers used in the building business and by auto manufacturers and printing ink and paint removers.

The MAL-code system works as a useful tool in relation to substitution. If, for instance, a company uses paint products with high MAL-code figures, it needs to find another product with lower MAL-Code figures to replace it with.

The association of Danish cosmetics, toiletries, soap & detergent industries (SPT) has launched a database containing more than 200 chemicals used in this industry.[26] Consultants from both the Institute for Water and Environment (DHI) and the Danish Toxicology Centre (DTC)[27] have prepared the database, which has now been send out to 300 different companies and institution. A copy can also be ordered from the web site: www.spt.dk (in Danish) The database still lacks data on a number of chemicals, but it is nonetheless a valuable tool for companies engaged in substitution. Similarly, the industry's international association, AISE, has, along with the primary chemical producers represented by CEFIC, started the so-called HERA project, www.heraproject.com. Within the framework of this project, 250 substances constituting up till 90% of the total number of raw materials found in their products, are assessed. A panel of external consultant is used. They carry out both risk and hazard assessments.

Figure 3
Paint product labelled with a MAL-code. The figure before the hyphen indicates the security measures to be taken after inhalation, whereas the figure after the hyphen indicates the security measures to be taken after having consumed the product or after skin has been in direct contact with the product. A low figure indicates low risks; high figure indicates high risks.

At the beginning of November 2005, SPT launched an SPT-charter directed towards suppliers of professional cleaning products. Companies that have obliged themselves to meet certain demands regarding ethics and the environment – including demands for certified environmental management – may use this charter. There will be an on-going re-assessment of these demands. SPT's members have voluntarily substituted the hazardous substances: nonylphenoletoxylates (NPEO)[28], MACs (cat-ionic surfactants) which belong to a group of quaternary ammonium compounds, and Triclosan, the antibacterial product found in cleaning products. In the future, the industry plans to look further into the use of fragrances, which may cause allergies or be hazardous to the environment.

The EU list of hazardous substances and the Danish EPA's list of unwanted substances are two tools, which can be helpful to companies, producers, product developers, procurement staff etc. when they plan to substitute. The list of unwanted substances contains more than 8,000 chemical substances and groups of chemical substances, which are all classified according to EU rules on classification and labelling of chemicals. The chemicals have been tested for hazards of explosion and fire, health risks, potential hazards to the aquatic environment and effects on the ozone layer. The list of unwanted substances is a guide aimed

26 www.spt.dk
27 DTC became part of DHI on 01.10.05
28 Nonylphenoletoxylates (NPEO) is the most commonly used but also the one most hazardous to the environment compared to other members of the group of alcylphenolethoxylates (APEO), which are suspected to have endocrine disrupting (hormone disturbing) properties. But the group of APEOs also include octylphenolethoxylates, which are equally damaging to the environment, and therefore not covered by the substitution in SPT. However, SPT believes that no APEOs are used in the Danish industry today.

at producers, product developers and procurement staff. The list contains the most important chemicals and groups of chemicals, which, according to the Danish EPA, may have problematic effects.

The Danish Working Environment Authority (WEA) has produced a list of threshold limit values that can be useful in connection with substitutions. The WEA has established accepted limit values for air pollution on the work place – the so-called threshold limit values. Chemical substances that appear on this list must be phased out in the work place whenever possible.[29]

Companies can use the ABC system or the UPH system to identify dangerous substances in their production. The ABC system groups the substances into three categories: Group A contains substances unwanted in the sewage system, and it is recommended that these substances be substituted with less harmful substances; Group B contains substances for which effluent requirements are recommended, while Group C contains substances that are not considered hazardous unless the discharged levels are very high. Similarly, the UPH system groups substances into three categories according to health and environmental effects. The three groups are: unacceptable (U), problematic (P), and manageable (H) substances. The UPH system is founded on the EU classification of health hazards. Both systems indicate which substances need to be phased out.

4.2 Means for Promoting Substitutions

'Green' taxation is one important means for the promotion of substitutions. There is a need for more 'green' taxes on hazardous substances. In Denmark, there is a tax on soft PVC and phthalates, and we have seen this work. In the same way, there ought to be put a tax on brominated flame-retardants and other hazardous substances. It would then be more expensive to use these substances and less hazardous products would be able to compete better. Eventually, more green taxes could lead to a ban on these hazardous substances.[30]

Public green procurement policy is another effective means. The public sector in Denmark has an annual purchase budget of 20 million Euros. All National institutions must have a green procurement policy, and the same is recommended to municipal and regional authorities. The state obligation is written in a circular of 1995 on environmental and energy considerations in procurement. The recommendation is part of a voluntary agreement between Local Government Denmark (the National Association of Municipalities), the Association of Counties and the Ministry of the Environment. Public procurement staffs who request environmentally friendly products can through bulk purchases influence the market. In order to secure a development of green procurement policies, there is a need for clear goals and for more encouragement. Despite the fact that many public institutions already have a green procurement policy, only a minority have so far made purchase decisions based on environmental arguments.[31]

29 AT (WEA) guideline C.0.1, April 2005, Limit values for substances and products (in Danish)
30 Read more on green taxation on www.ecocouncil.dk and www.mst.dk
31 More information can be found on www.mst.dk, www.kl.dk and www.ecocouncil.dk

Similarly, Eco-labelling is an effective way of securing environmental awareness amongst consumers, seeing that this labelling system provides consumers with an easy to follow guidance to the most eco-friendly products. It is vital that unsafe chemicals are removed from eco-labelled products such as cleaning products, electronics, fabrics and building materials. At the moment, companies pay for their eco-label licenses. This, however, hampers the extension of the substitution principle, and therefore the licenses ought to be free of charge. In addition, more pressure needs to be put on companies who have been reluctant to meet the criteria of the eco-labelling system. The Danish EPA has completed a project on directions for environmentally desirable shopping (www.miljoevejledningen.dk) – the directions take into account the effects of hazardous chemicals.[32]

Finally, environmental management and environmental certifications (EMAS or ISO 14000) are worth adding to the list of means for promoting substitution. Environmental management and certifications compel the companies to map out their environmental status, to formulate an environmental policy and set goals for the future environmental standards of the company. This means that hazardous substances or processes may need to be phased out in order to meet these goals.[33]

Figure 4
The Swan and The Flower
Usually, products carrying the Nordic Swan-label or the EU Flower-label contain fewer chemicals hazardous to the environment compared to other products belonging to the same category.

32 See eee.ecolabel.dk

33 More information can be found on www.mst.dk and www.ds.dk (The Danish Standards Association)

5. Danish Companies Substitute

A number of companies have already proved that it is possible to substitute hazardous chemicals with chemicals less hazardous or even completely harmless. The following case stories are examples of substitution projects carried out by 14 different companies. The case stories will describe the processes and include descriptions of challenges as experienced by the companies during their substitution processes. Both small and large companies, as well as small- and large-scale substitution projects are included.

5.1 Brødrene Hartmann

An interview with Jacob Nyborg; Project Manager and Lene Andersen; Lab Manager at Skjern Paper Factory.

Brødrene Hartmann A/S produces egg and fruit packaging from re-cycled paper. Hartmann is a global operator which employs 2600 people. The Group has, for a number of years now, focused intensely on internal environmental policies and management, including life cycle assessments and assessments of chemical substances used in the production. They avoid substances that are found on the EPA's List of Unwanted Substances. Each production company has its own environmental management system, which includes green accounts. Furthermore, every year the ABC-system is used to identify chemicals, dangerous to the environment and human health, and this way determine which substances ought to be phased out. If a substance belongs to group A, it is recommended that a substance less damaging replaces it.

Hartmann assesses the damaging effects of the substances throughout their entire life cycle, including the supplier and waste removal stages. The company insists that their sub suppliers meet certain environmental and work environmental demands. And where costumers request products, which require the use of damaging substances, Hartmann confronts them with issues of environmental protection. This way, the company, at one point, succeeded in convincing a costumer to accept a product in which the substance Sursol*VL had been substituted, after they have been informed that this had resulted in a product of slightly lower quality. A similar example is the substitution of a mixture of paints that took place at a newly purchased factory.

Substitution of Sursol*VL

Skjern Paper Factory is owned by Hartmann and has 74 employees. The idea of substituting Sursol*VL came from a costumer, who contacted the factory with a request for paper containing Sursol*VL, an intumescing substance which can make the paper softer and nicer. The competitor was also capable of delivering

this product, and therefore they had to contest if they wanted to secure the order. Before a new chemical substance is used, it undergoes an assessment. Sursol*VL was assessed at Hartmann's department for sustainable development, where it was found that the substance is harmful to the environment as well as the work environment. It was classified as irritant and damaging to the environment. At Skjern Paper Factury, they are much aware of which substances are discharges into the local River Skjern. Hartmann decided not to use Sursol*VL, and they contacted the costumer and presented them with the results from the assessment. It was then decided that Hartmann should try to find an alternative within 3 months. First Hartmann contacted their producer, but this gave no immediate result, and they therefore had to find a new producer. After 3 months had passed, the new producer had found an alternative, only it was not quite as effective as Sursol*VL. The new substance was Rheocol ACP. It was presented to the costumer, and the differences between this and Sursol*VL were explained to them. The costumer chose the new product despite the slightly poorer quality. "*In our experience, the costumers listen when we explain to them the environmental and health effects. And often they are willing to pay extra for products with less damaging substances*" (Lene Andersen).

Hartmann has to assess the chemical substances used in their production and send the result to the relevant authorities for approval. Rheocol ACP was approved. It was expensive to use this substance, as many resources had been spent on its development and on the collection of its data. The costumer became more aware of environmental issues after having worked with Hartmann on the project of finding a replacement for Sursol*VL, and, consequently, their own production is now more environmentally friendly. "*You have to consider all consequences, as a substitution can be too expensive. Hartmann spend resources on developing environmentally friendly products all the time. Therefore it is difficult to say exactly how much was spent on the Sursol*VL project alone*" (Lene Andersen).

Had the costumer declined the new substance on account of the poorer quality, Hartmann would have tried to have Sursol*VL approved instead. But the costumer believed that environmental protection was more important than quality and money. Today, Sursol is never used. Instead cleaner and better raw materials are used, which, in turn, is a result of the substitution mentality. The intumescing substance raise dust, therefore the substitution had helped improve the working environment. Before a new substance is used, it needs to undergo an assessment for working environmental effects. Instruction sheets must be put

up in the factory so that the employees know what to do, if the substance comes into their eyes or if some of the substance ends up on the floor. Furthermore, the new substance must go through a trial period before it is finally accepted.

The substitution project was a success and it was fairly easy to find an alternative. Skjern Paper Fabric has gained more costumers, because the message of their environmentally friendly products and their willingness to inform costumers about environmental effects has reached a wide audience. But this is not an effect of the substitution of Sursol*VL alone.

"*It has been a challenge. It is an on-going process, and we are still working on the substitution*" (Lene Andersen).

Outline of the Chemicals Related Problems after Purchasing a new Factory

5-6 years ago, Hartmann bought a new factory in Brazil. The use of chemicals was far from environmentally friendly at this factory. Therefore Hartmann performed an assessessment on all chemical substances – the use and dosage. It turned out that they were extremely dangerous chemicals. The workers were not properly protected and often the substances were overdosed. Consequently, Hartmann introduced an environmental management system, including rules on dosage, plans for future substitutions and instructions on how to manage the various substances. Powder paint was replaced by water-based paint. The danger of being exposed to powder paint is greater than the danger of being exposed to water-based paint. A new supplier was found, as the existing one was not capable of supplying the desired chemicals. On the whole, everything was systematised properly at the new factory.

The renovation of the newly purchased factory has been expensive. But it contributed to an improved image as a company that cares about the environment.

Results from the Substitution

"*Hartmann takes a positive stand when it comes to performing substitutions, and the substitution has been a positive experience. We have seen positive results from involving our costumers, and now they understand better why our products are a little more expensive*" (Lene Andersen). Most costumers chose the least harmful product if presented with the environmental facts.

"*Demands from our costumers and the fear of negative press have been the main motivators. But, of course, we also would like to have an image of being a company that is concerned about the environment*" (Lene Andersen). Costumers contact Hartmann because they know they care about environmental issues. Costumers such as Nokia, Sony, Phillips etc.

prefers packaging without harmful chemical substances. They need to be able to use the packaging worldwide, without breaking any environmental laws.

Hartmann often involve employees and knows how important this is. The same goes for sales reps, buyers and product developers. "*It is important that the sales reps know exactly what they are selling and what they need to tell potential costumers*" (Jacob Nyborg). *It is important that all employees feels responsible and that their opinions matters. Therefore, all employees are more or less involved and engaged in the substitution*" (Jacob Nyborg).

Facts on Sursol*VL

Sursol*VL is used to soften cardboard. Sursol are ethers formed by ethoxylated- or propoxylated aliphatic alcohols with 12 – 18 carbon atoms. The alcohols are primarily linear. The structure of the propoxylated, linear, primary alcohol with 12 carbon atoms is shown below:

$CH_3 - (CH_2)_{10} - CH_2 - O - CH_2 - CH_2 - CH_3$

Sursol*VL is classified as dangerous for environment. It is severely toxic to organisms living in water, and it is suspected to cause long-term damage to water environments. Furthermore, Sursol*VL affects humans, as it may cause skin irritations, and it is therefore classified as irritant. It is recommended that people working with Sursol*VL carry protective clothes and eyewear, and avoid inhalation.

5.2 Abena

An interview with Jørgen Nellemose; responsible for environmental issues, quality, social responsibility and ethics.

Abena Produktion A/S was founded in 1980. The company's original name was Bambo Produktion A/S, but the name was changed in the year 2003 to the more internationally sounding Abena Produktion A/S. The company, which employs 350 people, specialises in the development and production of personal hygiene products. Primary target groups are institutions such as: hospitals, retirement homes, childcare centres and schools. Abena has departments and production facilities scattered around the world. The company is responsible for the most advanced absorbing personal hygiene products – such as diapers – currently available on the market. More than 90% of Abena's total production is exported to more than 60 different countries. The company has no sales department, as one company – Abena A/S– is the only purchaser of Abena's products. Jørgen Nellemose is responsible for all environmental issues at Abena.

Several of Abena's own products are licensed to carry the Nordic Eco-label, The Swan. Abena does not permit environmentally damaging products to be part of their own production. It is required that all suppliers give a detailed account of every raw material used, including accounts of their impacts on the environment as well as on human health. No values are allowed to exceed recommended threshold limit values, and Abena prefers for its suppliers to be certified to the standards of ISO 14001 or EMAS. In order to ensure that supplier's production facilities correlate with Abena's environmental standards, visits to factories take place frequently.

Abena holds an ISO 14001 certificate. Issues of quality and the environment are taken into account on a daily basis, and the management system includes all activities associated with acquisition, storage, sale, delivery and education. It is Abena's sheer ambition to increase the percentage of products, which qualify for environmental labelling with at least 5% yearly. The Swan label is used in Scandinavia, but local labels are used elsewhere. In Germany, for instance, the eco-label is The Blue Angel. Moreover, Abena performs environmental accounting.

In Abena's own research and product development focus is on a reduction of raw material usage and on minimising the damaging effect on the environment. All materials used in the production of diapers are reused, whereby paper and plastic waste are reduced to an absolute minimum. Diapers which are sorted out undergo a recirculation process by which paper and plastic materials are separated. Without causing further problems the paper pulp can be reused in the production of new paper, and similarly, the separated plastic is compressed and returned to the plastics industry, where it can be used in the production of new plastic.

Substituting to Environmentally Friendly Diapers

It has been one of Abena's primary goals to produce eco-friendly and Swan-labelled diapers. Their product Bambo Nature is the first Swan-labelled diaper ever to be produced. When Abena first sat out to produce a Swan-labelled diaper, they started out by examining the Swan-label requirements. This was followed by an investigation of suitable substitutions for raw materials in the existing product. They decided to substitute parts of the super-absorbing agent. Before the substitution process, the absorbing agent was based on acrylic acid, and now after the substitution process the agent is based on wheat starch and granulates. The new absorbing agent is as effective as the old. In addition, the company found that the old sizing material could be substituted for a mixture of resin and vegetable oil. Likewise, the old top band was substituted for a mixture of lycra and plastics. Today's Nature Baby is made up by 80% paper. The paper used in the production stems from Scandinavian sustainable forests. Only new paper is used. The paper is bleached using hydrogen peroxide, thereby avoiding the use of chlorine. In addition, the diapers do not contain phthalates, and only vegetable dye is used. Finally, Bambo Nature is the only diaper on the market not containing an acrylic acid based super-absorbing agent.

The substitution project is a result of cooperation between the management team and the environmental issues department. All research took place in Abena's own laboratory, and tests were carried out using Abena's own equipment. A team with the task of following and guiding the process was formed, consisting of employees from the sales department, nurses, employees from the production unit, members of the management team and with Jørgen Nellemose as responsible for environmental issues. By forming this team, Abena managed to avoid many problems. "*It was important for us to involve all affected employees in this project. In this way the project became more enjoyable for everyone, and it created a sense of ownership amongst our employees. Otherwise, it could easily result in a sense of indifference.*"

The motivation behind Abena's substitution project was an aspiration of becoming a green alternative on the market. "*The competition is massive, and we are not one of the major players on the market. Therefore, we wanted to do something that would make us stand out from our competitors. And as we always wanted to see ourselves as a green company, we wanted to stand out by being green.*" The idea behind the substitution process came, first of all, from within the company, though there was some pressure from outside as well. Demands for environmentally friendly diapers were modest. This meant that Abena had to go out and create a marked for this product themselves. However, public institutions are required to buy the most environmentally friendly products on the market; this gives Abena the upper hand compared to other producers. "*It is rather our wish to appear as eco-friendly, and that is why we have an eco-management system and what follows therefrom*". When producing Swan-labelled products, companies do not need to also verify the products as non-damaging for the environment and for public health. This saves time. "*The Swan-label makes us focus more and more on the environment in relation to our production, seeing*

that the criteria for the label become more and more strict. Therefore, we cannot allow ourselves to just lean back and relax."

Experiences, Rewards and Work Satisfaction in Relation to Substitution

A substitution process can be expensive as it often requires for the production procedure to be altered. For Abena this meant investing in new technology, as the old machines were not able to produce the new eco-friendly diapers. "*We have decided to aim at a production consisting almost solely of Swan-labelled products. It has been a major investment. Had it not been for us wanting to be known as a green company, we probably would not have made the investment at all. But not doing it would be setting a double standard. It is an investment.*" Therefore the new products are not more expensive compared to the old products. "*We did not feel it was right to increase prices*."

Finding alternatives has not been an easy task. Substitution possibilities are limited. There are not many suitable substitution materials, and often the new materials are extremely expensive. "*In fact, it is possible for us to produce a diaper that is 100% biodegradable, but no one would be able to afford it. In stead, we are taking the process step by step. Substitution is constantly in the back of our minds.*" Bambo Nature was launched in 2001. But Abena continues to develop this product. Up until very recently, Bambo Nature has not been available for private consumers but only for institutions.

The substitution project has had a positive side effect in the form of an improved working environment. The old super-absorbing agent was not directly damaging to human health, but it goes without saying that it is always better to work with eco-friendly materials. Overall, the substitution project has been well received amongst employees at Abena. "*Our sales reps are proud to be selling a product that has been proved to make a difference – it is not just empty sales rhetoric. We can prove that we are making a difference. Bambo Nature has been part of our production for more than 3 years, and we plan to continue the making of this product. Bambo Nature qualified for the Swan-label 4 years ago, but later on, the label was withdrawn as the requirements had changed*." The substitution process has helped improve the company's green image.

"*I am positive that the substitution project – together with other factors – has bettered teamwork at Abena. Job satisfaction is closely linked to our environmental management system and to other steps towards an eco-friendly company policy. To name one thing, diapers with minor defects are sold in Holland and Poland, or given away in Ukraine – they are not simply thrown out*."

"*Substitution can be recommended to everyone. The idea of substitution and the substitution process itself are very fascinating. The reason being that it is all about thinking ahead and constantly developing and improving the products. My job would not have been half as exiting had it not been for that. The substitution project involving eco-friendly diapers and having them meet the require-*

ments of the Swan-label has been very exiting – especially since we were the first to do it."

Facts about Acrylic acid

Acrylic acid is an unsaturated, aliphatic carboxylic acid with the following formular:

$H_2C = CHCOOH$

Due to its highly reactive doublebond, acrylic acid is easily polymerized or taking part in polymerisation processes as basis for production of superabsorbing materials.

Polymerisation of acrylic acid:

$$- CH_2 - CH - CH_2 - CH - CH_2 -$$
$$\quad\quad\;\; | \quad\quad\quad\;\; |$$
$$\quad\quad COOH \quad\quad COOH$$

Acrylic acid is corrosive and dangerous by inhalation, oral intake and dermal contact, and it is very toxic for aquatic organisms. Acrylic acid is listed as dangerous according to EU regulations.

Acrylic acid being the basic raw material in the production of superabsorbent, it is primarily this process, which makes the hazards important and relevant in relation to workers as well as to the surrounding environment in cases of loss and/or emissions. Superabsorbent as separate material is apolymer in its own right, however not registered as toxic.

5.3 Danfoss

An interview with Lone Damm; Senior eco-, process- and material consultant.

Danfoss produces products within the areas: refrigeration and air conditioning, heating (valves etc.), motion controls (frequency converters etc.), industrial controls, water controls and water hydraulics. It is a family owned global company with 17,500 employees worldwide. In Denmark, 6,000 people are employed by Danfoss.

All factories owned by Danfoss have introduced an environmental management system certified according to the international standard ISO 14001. Moreover, Danfoss has joined the UN Global Compact, which involves nine principles concerning social and environmental responsibilities. Each year, Danfoss produces a report on the company's policies in relation to environmental issues and on the effects their actions have had on the environment. The substitution of metal working fluids is a result of the joined efforts of Danfoss' Technology Centre and the Danfoss Group. This teamwork reflects the fact that Danfoss has pioneered this field. For instance, Danfoss was the first company in Denmark to frame a list of demands aimed at their suppliers. These lists came into effect in 1984, and in 1992 demands for preliminary tests of the metal working fluids were added.

The Substitution Process

Initially, the idea of substituting the metal working fluid was presented to the management team by the department for environmental issues at Danfoss. In other words, concerns for the environment – and not hopes for increased profits – was the main motivator. Thus, Danfoss was aware that this material was problematic and that it would be difficult to find a suitable substitute. On the other hand, they knew that it was important to find a solution to this problem. Therefore, they decided to form a team of selected users, whose purpose it was to find a substitute for the chlorine-based oil in the metal working fluid. It was important for them to find a way to substitute without making the production more expensive and without having any negative effects on the employees or on the environment at any stage of production, usage and waste handling. In addition, it was important to find a material, which was technically equal to the old material.

Several meetings about the project were held and all new information about the project was immediately passed on to all employees involved in the production. This way, both members of the management team and the people working on the machines became involved in the project. "*In the trial period, it was*

important also to involve the people working on the machines. They know what to look out for when the alternatives are tested, and they are also the ones who can assess the new procedures and determine whether or not the new material is comfortable to work with." It could be, for instance, that the new material had an unpleasant smell, i.e. having qualities which would not be noticed if only seeing the end product. Therefore, the ongoing dialogue with all involved workers was vital. It was a way to avoid for the whole process to be set off, only later to be stopped because the working conditions for the people working on the actual production were too poor.

Chlorinated paraffins – both medium- and long-chained – is the problematic group of hazardous substances which can be found in the metal working fluid. In Danfoss both low, medium and highly chlorinated oils have been used, but they have now been substituted with additives of which many were sulphur-based or fatty oils such as vegetable and animal oils. "*Then one might say: can it be better to burn off sulphur? That process produces sulphur dioxide*." High levels of sulphur can create problems of smell, which can be discomforting for the people working on the production. Moreover, getting rid of waste products will be a problem. Danfoss has – in consultation with the suppliers – worked out a way to avoid high levels of sulphur. They have introduced phosphorus- and zinc compounds. "*Regarding the alternatives, heavy metals could be a problem. But it is a matter of finding a way to reduce the risk. It is not possible to simply say that we do not want any of those chemicals to be part of our production – because then we would not be able to carry on with the production at all*."

In order to find a substitute for the chlorinated paraffins, Danfoss had to examine their production processes in detail. "*We had used 7-8 different chlorine based oils, and now they have been substituted with 5-6 non-chlorine oils*." Initially, when a production line is designed, not much thought is given to secondary materials – you simply use the materials closest at hand. But when you are forced to examine the production processes in detail, you automatically become more aware of which requirements to make. "*Hence, it is very useful to go through your processes once in a while*" As an example, Danfoss became aware that the production flow could by optimised by eliminating unnecessary steps in the production process. An unwanted degreasing process could, for instance, be avoided. "*It is useful to see things from a different perspective. There is, for instance, one process, which involves a large amount of oil spills, which then strains the following washing process. By being more aware of the production processes, we have managed to prevent things like that, and we have had more positive results from the project than we had imagined*".

The substitution process began in 1989 at which point Danfoss used 250 tonnes of metal working fluid containing chlorinated organics. But in 1991, this has been reduced to less that 15 tonnes annually. The substitution project continued, and in 1997 the figure had been even further reduced, as now only 7 tonnes was used on a yearly basis. Today, Danfoss still uses around 7 tonnes per annum. It is believed that the remaining part of the material cannot be substituted using material-substitution. Instead, process-substitution must be applied, resulting

in a combination of solutions, involving the choice of materials, e.g. stainless steal which is not readily processible and a process, which requires a great deal of lubrication. Tools and surfaces of the materials, therefore, must be reconsidered, and maybe it is necessary to consider changing the production methods. "*Material-substitution is the easiest method. Here one material is simply substituted with another. But in many cases this is not enough. Sometimes suppliers argue that if we are dealing with a compact subject vulnerable at high pressure, it is necessary to use chlorinated paraffins. It is a situation where it is difficult to find a solution unless we take a close look at the processes.*"

Challenges and Obstacles

Convincing all employees that it is a good idea to embark on the substitution process has been a challenge. Some seem to think that everything is fine the way it is, and they do not see the need to change anything. Another challenge has been to run the tests. Here the argument has been that we should go directly to the production, i.e. without testing. "*It has been difficult to run tests at our own production premises. We do not have a research unit or a special testing machine*". It has been difficult to create a sense of ownership amongst our production workers. Furthermore, it has been a challenge just to understand the overall problem, to organise the running of the tests, to establish the criteria for success and to get hold of the best suppliers. If an error occurs during the tests it can have major consequences for the production. Expensive tools can break and sometimes it may take weeks before they can be replaced. In addition, if it is a busy period, it can be difficult to see why the production workers should take time out of their schedules to run the tests. It can be difficult to see the positive effects, which has been one of the main obstacles.

Economy and Resources

The reduction of the number of steps in the production process has had positive economic side effects in the shape of a reduction of variable costs. "*In many cases it was possible to eliminate steps from the production process. This was because focusing on the process has made it possible to minimize the requirements for a subsequent degreasing. This way the production run was shortened. By focusing on the production process, it has been possible for us to optimize our production. So when I think of it this way, I believe we have seen positive effects from the project.*"

The substitution project has been costly because of an increase in man-hours. For a period of approximately two years, Lone Damm has devoted more than half her time to the project. So, it is a time consuming project. And the company has to be willing to spend time on the project in order for it to be a success. Normally, substitution projects are not seen as an investment, as in order for a project to be so, the company has to believe that it will bring about a reduction of variable costs or a wider clientele. But these things are impossible to predict. "*People are starting to see the substitution projects as something which can involve positive economic results. This is because we have seen several examples of this. So this way we can see environmental projects as something positive for the company's economy. But often, substitutions happen as a consequence of external demands. However, if it turns out that the project has positive economic side effect it is easer to view it as something positive for the company*."

Danfoss has experienced cost-savings as a result of the substitution. New metal working fluids have been developed and the production run has been reduced. "*If you buy the right metal working fluid, it will last you longer and you will the save money on new purchases. In addition, there has been fewer complaints, less wear and tear and the tenability of the tools are prolonged*."

Results and Challenges

The reduction of the amount of chlorine-based coolant from 250 tonnes to 15 tonnes has been rather easy. But after that further reduction was more difficult, because many different suppliers had to be involved in the process. "*You start to notice who has an environmentally friendly approach. It has been necessary to get more suppliers involved*."

The substitution process has been a challenge to the employees, and it has provided them with knowledge, which can be put to good use in the future. When all the arguments for a substitution process were presented to them, most of them expressed a positive attitude towards it. "*The decision was made by the management team, and I think it is important to secure the support from the managers right from the beginning. I have been part of several substitution processes now, and in my experience, employees tend to have a more positive attitude towards the project, if they get involved and they are asked their opinions on how they feel about the project. In fact, sometimes one of them phones me up and says: "I think you ought to know this or that." So in most cases, the employees play an active part throughout the whole process. And to me, this is a sign of them having a feeling of ownership and of us taking them seriously. This is a very important part of the substitution process.*" Danfoss believes that working with the people working on the production is vital for the project to be a success. If the people working on the production are not involved in the substitution process and someone from outside the production just shows up and says: look, we have found the best solution – then chances are that motivation amongst the people working on the production is not that great. There needs to be a sense of ownership from the very beginning.

The users got involved in the project. Some key persons ran the tests – mostly

organised as a team. "*You need to take a look at the actual needs of the production. In consultation with the suppliers we try to uncover whether they are capable of delivering oil suitable to our needs.*"

"To me, this process has resulted in an expanded network – both inside and outside Danfoss. If you want to embark on something, which no one has embarked on before, you need to go through your network. The substitution process has been characterised by communications between the users and the suppliers. Clearly, it is vital to stick to all agreements made with everyone involved, as you want to form long-standing relationships with them. So if you look at it that way, the process has been very rewarding. Moreover, it has involved a number of technical challenges, seeing that I was dealing with a field, which had previously been unknown to me. I now have more knowledge about toxicology and various environmental issues. In fact, I now have enough technical knowledge to maintain a view over the entire project. I spoke to many of the developers at our suppliers, as I often consulted them instead of their managers. In our production the job satisfaction increased, when the workers were involved in the substitution project. They sat in on the meetings with the suppliers and this way they were able to present their own viewpoints."

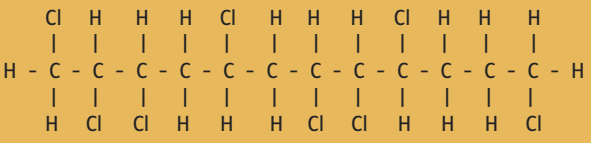
Regarding new costumers, the substitution project has been a success. Employees from several of Danfoss' different departments have contacted Lone Damm because they have been asked by costumers about the company's use of substances critical to the environment. Typically, these queries come after an introduction of new rules or laws. For instance, when the Rohs directive was introduced, companies began to worry and wanted to make sure that the substances on the list were not used in their production. Likewise, when Danfoss' costumers want to make certain that Danfoss are not using a specific feedstock, the company needs to be able to provide evidence that that specific feedstock is not used in any of their productions. So in that sense, the substitution can be very beneficial. "*I believe these things are important to Danfoss' green and environmentally friendly image. Danfoss is looked upon as a company being in control of things. And I think the substitution project has a positive effect which will never harm the company's reputation.*"

"*I can strongly recommend other companies to do the same. The most important thing is to have the support of the managers and of course to formulate a proper description of the project and to hire the right people for the job – people who has the right know-how. In addition, it is important to find the right suppliers.*"

Facts on Chlorinated Paraffins

Chlorinated paraffins are a group of chemicals used in coolants and lubricants, in paint, plastics and flame-retardants. Chlorinated paraffins are aliphatic hydrocarbons with chlorine bound to part of the carbon atoms. They are divided into short-chained (having 10-13 carbon atoms), medium-chained (having 14-17 carbon atoms) and long-chained (having 18-30 carbon atoms). And we distinguish between chloroparaffins containing less than 50% chlorine and chloroparaffins, which have chlorine content greater than 50%.

Below is shown an example of a short-chained chloroparaffin (12 carbon atoms) containing more than 50% chlorine:



Chlorinated paraffins found in coolant are medium- and long chained. They are added because of their lubricating properties at high pressures and temperatures.

When coolants containing chlorinated paraffins are used, the substances will be spread widely in the external environment including in wastewater and in contaminated soils. It is estimated that around 25% of the total amount of coolants used will remain on the metal chips used to produce new steel, and the chlorinated paraffins will consequently be burned. The waste is treated at Kommunekemi. When chlorinated paraffins are burned, dioxins and dibenzofurans are released. Dioxins and dibenzofurans are chlorinated aromatic compounds, which may be acute toxic; they have carcinogen effects and may cause other serious health damage. Besides, dioxins and dibenzofurans can accumulate in breast milk. At the production stage, workers are exposed to the chlorinated paraffins through skin contact or inhalation of dust or mist. At the stage of waste removal, the substance may be absorbed through skin, which may cause skin irritations or eczema.

Chlorinated paraffins are found on the Danish EPA's List of Unwanted Chemicals. Short-chained chlorinated paraffins have been risk assessed by the EU. They are on the list of prioritized substances in the thematic field of water policy, including the water framework directive. Restrictions are imposed on the use of short-chained chlorinated paraffins. They must not, for instance, be used in coolant. Furthermore, they are classified as PBT (persistent bio-accumulating toxic) substances, and they are on the List of Dangerous Substances. Short-chained chlorinated paraffins are classified as carcinogenic and as dangerous to the environment. The EU is currently risk assessing the medium-chained chlorinated paraffins, and long-chained chlorinated paraffins are currently undergoing a voluntary risk assessment in the EU.

DANISCO
First you add knowledge...

5.4 Danisco

Danisco is the world's leading producer of ingredients for the food and beverage industry. The company was founded in 1872 and today Danisco has production units based in Europe, the US, Mexico, South America and in Asia. The company employs around 10.000 people altogether in 40 different countries. The main part of Danisco's production consists of ingredients for the food industry, whereas the production of sugar is only a minor part of their total production. Furthermore, Danisco helps their customers in the food industry improving their production methods as well as developing new products.

Danisco has a centralised department for sustainability. This department deals with environmental issues as well as issues concerning social responsibility and food control. In addition, each of Danisco's companies employs a person responsible for issues of sustainability, and Danisco plans to incorporate the idea of sustainability into all activities related to the production. This is done, for instance, via a reinforced co-operation with their suppliers. According to Danisco, the term sustainability refers to a combination of quality, safety, environment and working conditions , and an annual report is published on the subject. "*A lot of effort goes into securing sustainability. This is because we think it is important*." Regular inspections are held at supplier's factories, and Danisco checks all raw materials before they are used in their production. The aim is to

reduce the expenditure of water, waste and energy. Furthermore, Danisco has an environmental management system.

Danisco has carried out several substitution projects, of which we have chosen two for our purposes. The first project involves substitution of phthalates and the second concerns the substitution of nitric acid at Nakskov Sugar Mill.

Danisco has Discovered Substitutions for Phthalates

An interview with Torben Svejgard; Chief Operating Officer

Danisco has developed a substitute for phthalates at their own research centre, which is a subdivision of the department for emulsifiers. Torben Svejgard is the former director of the department for emulsifiers and, therefore, he was part of the project from its very beginning. The department for emulsifiers is based in Aarhus, where a total of 480 people are employed.

The Substitution Project

Danisco developed a substitute for phthalates based on Castor oil. As it is often the case with new inventions, this discovery came from a combination of coincidence, luck and an ability to utilise experiences from the company's every day processes. More specifically, the discovery of the Castor oil product as a suitable substitute happened via the production of emulsifiers. Emulsifiers bind water and fat and they are used in margarine, bread and ice cream. Emulsifiers can also be found in plastic films used as food wrapping. Here they are used for anti-dew and anti-static purposes.

Danisco knew that one emulsifier already used in their production had a softening effect. In fact, they have sold smaller amounts of this material as a plasticizer. It is made up of acetic acid and vegetable oils, but it never had the same softening effect as phthalates. At one point Danisco's research centre was running some tests, which had no immediate connection to the substitution project. But during these tests, one of the employees noticed that the castor oil product had characteristics previously unknown to him. He suggested that Danisco took a closer look at this material. "*We knew from our contacts that others were trying to find alternative emulsifiers, so to see if anything could come out of that, we decided to do some preliminary work on the project ourselves. But quite often projects like this never really gets off the ground*." The results gained from the preliminary work turned out interestingly, and therefore they decided to embark on a substitution project. After this, Danisco began to work systematically on the project of finding alternative emulsifiers. And once they knew in which direction to go, it was easy to continue the development – the most troublesome part was to run the tests.

The new products were tested by 5 -10 of Danisco's customers. The idea was to make certain that the products worked before investing hugely in the project. Danisco decided to focus on 3 production areas: food wrappings, children's toys and medical equipment – the preliminary tests focused on the same 3 areas.

"*Ideally, we wanted to have the products tested by more producers. But several of them held: "That is all very well, but why should we waste our time on that. You might never get them accepted." – And I do understand that way of thinking. The same thing happens when suppliers come up to us with similar ideas. Then we also want to think the whole thing trough before going through with such projects. Today, it is difficult to get new products approved.*" Danisco applied for a patent in 1999, which means that the product had been ready for more than 4 years. The last 4 years have been spent on tests, which will prove that the product is safe; whereas, the actual development took less than two years. Now the product has passed the first part of the approval procedure. Approximately 10 people have been involved in the development.

Expenses in Relation to the Substitution Project

Most of the expenses have been related to the approval process, and less money has been spent on the actual development and testing of the product. All in all, Danisco has spent several million DKR on the product – most of which on tests and analysis as part of the approval procedure.

The new product is more than 3 times as expensive as the old one. Therefore, Danisco is anxious to find out if they can actually sell this new product. "*Personally, I think we can sell the new product. But I do not think we will see all producers who use phthalates to completely convert to this new product. However, if we can get 1% of the market share, we will be satisfied.*" One of the reasons why Danisco has decided to focus on the three areas – food wrappings, toys and medical equipment – is that these are areas where consumers are willing to pay extra for their products. It is obvious that if it were possible for Danisco to sell the new product at the same price as the phthalates, they would immediately start building several new factories. But the costs of feedstock alone are considerably higher than the costs of phthalates; and on top of that come the costs of the actual production. "*The new product will never be as cheap as the old ones – therefore there are limits to this new product.*" However, Danisco is positive that once they start selling larger amounts of the new product, they will begin to make considerable profits. Another hindrance is that there are other alternatives to phthalates on the market. These are in use already, and it is difficult to convince costumers to try yet another alternative. In addition, Danisco's product is expensive compared to other alternatives on the market – but it is probably safer. "*With a large scale production of the new product, it is possible to reduce our expense slightly. Still, our product will be 2 or 3 times the cost of the other alternatives.*"

Challenges and Experiences

The substitution project has improved Danisco's image. After Danisco had introduced their new discoveries, the companies received a great deal of attention from the media as well as from people working within the same industry. "*There is no doubt that producers of plastics would love to substitute all phthalates if only they could get consumers to pay more for their products. Additionally, there is no doubt that our image has been improved as a result of the project. That is a very positive side effect.*"

The substitution project has made Danisco stop and think about other potential areas where substitution could work. "*Can we apply our experiences from the food industry on to the industry of plastics? Our strength seems to be a different starting point compared to companies producing plastics.*"

"*People have been very pleased about the new discovery. And now we are very pleased that the product is approved and we can market it.*" Especially, those who worked on the actual development enjoyed the process, "*but of course, there will always be both positive and negative surprises when a new product is introduced.*" The approval procedure, for instance, has been a long and tiresome process for the employees. And none of them were capable of foreseeing how much work it was necessary to put into that process. Danisco was familiar with the approval procedures for the food industry, but this was the first time where they had to go through the process with a non-food product. "*We had been naïve to think that it would be fairly easy to get the approval. I am not saying that this is completely wrong, but I know it has, at certain times, been a somewhat frustrating process to our employees, and they became impatient in the long run. Everyone knew that it had to be done, but sometimes the demands were simply too bureaucratic. In general, our employees are very conscientious people, and they really wanted to offer a safe product. Therefore it has been frustrating. Everyone who knows what he or she is talking about said that our product is safe. And needless to say, compared to other products on the market this one is truly safe. A lot of our employees feel that things are not put into perspective, and everyone believed that in order to be able to justify the substitution project, it really had to be carried out properly – but these demands were a bit over the top.*" The approval procedure has been frustrating and in fact it still is. "*Personally, I*

think it has been an interesting project, but I have also been frustrated because of the EU's protracted approval procedure. To them, 6 months are nothing. If they do not manage to consider the application at one meeting; well then maybe they will manage to take care of it at the next. Meetings are held every 3 months, but to us 3 months is a long time."

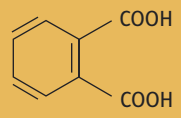
Another difficulty has been to convince costumers to get involved and to test the product before we had the approval. It seems to be a case of the egg and the hen. Danisco believes that the product is good, but they cannot know for sure before the consumers have tested it. But customers cannot know if it is a good product before it has been produced on a large scale. But the problem is that they cannot produce the product on a large scale before they have the approval, seeing that they risk having to throw it all out, if they end up not being allowed to sell it.

"*We spend more money on the development of environmentally friendly products than is required of us. We are far ahead of the local legislations in all the countries where we are represented. This is because we believe that it is right, and because we believe that is the proper way to run a business. Hence we also see things from a business point of view. Today, it is not possible for any company to survive without having an ethical profile; and I believe that is the way it should be. Of course, this is not the same as saying that no one can make any mistakes at all; but at least everyone ought to try their best.*"

Facts on phthalates

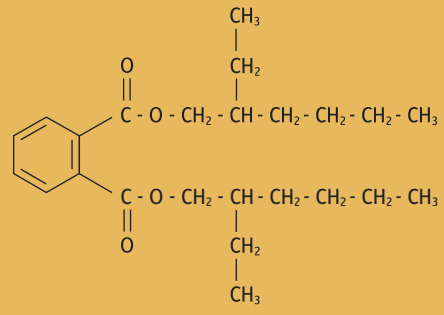
The name phthalates refers to a group of different esters of phthalic acid (see formula below). They are mainly used to soften PVC. Some phthalates are used to make nail varnish flexible or to make perfumes linger longer. Others are used in adhesive plaster, sealings and in artificial colourings – to make them stronger. Phthalates are also found in products such as raincoats, rubber tubes, medical devices (e.g. tubing and bags), textile printings, children's toys, cables, glue etc.

Phthalic acid:

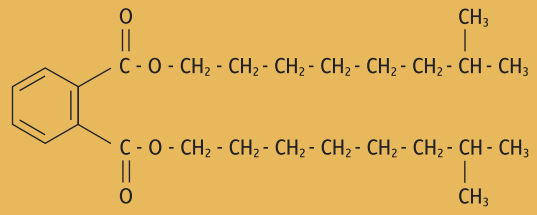


The phthalates are released from the products during the production process and during the use and discharge of the products. When added to PVC, the phthalate-molecules bind to vinyl molecules after which the molecules begin to slide against one another but without loosing strength. After a period of time has elapsed, there will be a certain migration of phthalates from the PVC. The content in soft PVC can be up to 50%. Phthalates are the most commonly used plasticizers in the world. There are many different kinds of phthalates and they vary in size and structure. The most commonly used are:

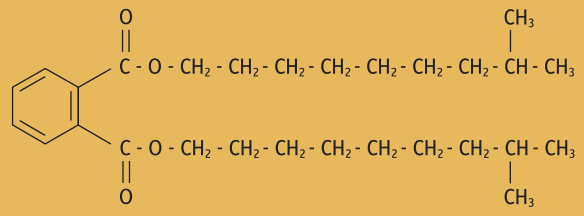
DEHP (Di(2-ethylhexyl)phthalate) – used to soften different kinds of flexible PVC products including medical devices, shower curtains, cables and children's toys.



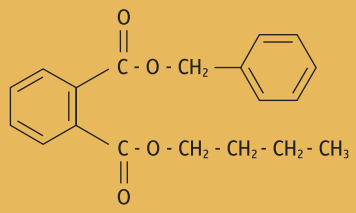
DINP (Diisononyl phthalate) – used in garden hoses, shower curtains, children's toys etc.



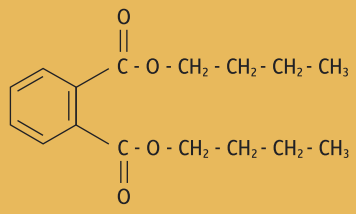
DIDP (Diisodecyl phthalate) – used in garden hoses, shower curtains, PVC flooring, electrical cables etc.



BBP (Butyl benzyl phthalate) - used in PVC flooring, paint products, lids etc.



DBP (di-n-butyl phthalate) – mainly used in the manufacture of cellulose polymer, inks and sealings. It is also used in small amounts in cosmetics and nail polish.



DEPH is the most commonly used phthalate. As phthalates are widely used and used in large quantities, they have been thoroughly tested for environmental and health effects.

DEHP has been classified by the EU as harmful to embryos (teratogenic) and as a cause of infertility (group 2). This means that animal testings have indicated that DEHP may cause harm to an unborn child and that it may be the cause of human infertility. This classification is founded on test results showing damages in embryos in mice and rats and damages to testicles in rats. This documentation represents sufficient evidence to conclude that humans may risk infertility and damages to embryos if exposed to DEHP. DEHP is on the EU list of substances with documented endocrine disrupting effects. Phthalates are found on the Danish EPA's List of Unwanted Substances.

There has been an increase in the use of DINP since the classification of DEHP. Both DINP and DIDP show signs of having harmful effects on embryos and fertility, but only when very high concentrations are used. Therefore, classification is not relevant in relation to these effects. But also DINP is found on the list of possible endocrine disrupting substances. Tests on rats have shown that DINP may have anti-androgenic effects – that is, inhibiting the effects of male sex hormones.

Both DBP and BBP have damaging effects on embryos and on sexual reproduction when tested on animals. DBP has been classified and is found on the list of dangerous substances. A risk assessment of BBP suggests that the substance be classified as teratogenic in category 2 and as a cause of infertility in category 3.

Phthalates are degradable if oxygen is present, but in the environment, the degradation is a very slow process – especially for DEHP, DIDP and DINP, whereas DBP is easier degradable. Phthalates can be found frequently and in all compartments of the environment, and they bind to sediments or soil. When phthalates are absorbed in living organisms, they are transformed into other metabolites and finally discharged. Especially, some of the metabolites are reported to be hormone disturbing. As a result of the abundant uses of the phthalates and their wide distribution, humans living in the industrial societies will regularly carry noticeable concentrations of phthalate-metabolites in their blood veins.

In Denmark it is illegal to use phthalates in toys produced for children below the age of 3. There is a similar EU law against the use of phthalates in toys, although in this case the law merely covers toys intended to be put in the mouth.

In 2005, the EU decided to put a ban on the use of three phthalates (DEHP, DBP, BBP) in all toys and other products aimed at children, and in addition to introduce a full ban on the use of the three other phthalates (DINP, DIDP, DNOP) in toys made for children under the age of 3.

Nakskov Sugar Mill Substituted Nitric Acid

An interview with Anders P. Andersen; production manager.

Nakskov Sugar Mill employs 170 – 215 people depending on the season. Danisco Sugar Nakskov was founded in 1882, and today they produce approximately 200.000 tonnes of sugar annually. Around 1600 different farmers deliver the sugar beets. More than 80 % of the production is sold on to the food industry and the rest is for retail distribution. Every day, 700 truckloads of beets – corresponding to 1.3 million tonnes – are transformed into sugar. Danisco Sugar feels strongly about Nakskov Sugar having an environmentally friendly profile. Every year, long term plans aimed at an environmentally friendly production are laid. Nakskov Sugar reuses waste products and hence closes the cycle. The company is certified according to ISO 14000 and every year environmental accounting is performed. Once a year, the company's environmental plans and policies are discussed with local authorities. This is to ensure that the company's plans correlate with local legislation.

Nakskov Sugar does not produce eco-labelled sugar, but other Danisco sugar mills do.

The Substitution Process

Substitution is an ongoing process taking place at the department for environmental issues at Nakskov Sugar. This department is solely dedicated to substitution processes.

The sugar extraction requires a list of subsidiary materials. As an example, hydrochloric acid and nitric acid is used to clean production equipment. It only took 3 months from the decision was made to substitute nitric acid till the project had been carried out. The discovery of citric- and acetic acid as suitable substitutes and all the tests were made at Danisco's own premises. Danisco experienced no difficulties during the process.

The substitution has had very little effect on the production. Furthermore, it was not necessary to find new suppliers, as the old ones were able to supply both citric acid and acetic acid. Nor has the substitution had any effects on the end product, and therefore consumers will not be able to notice the difference.

Before the substitutes were introduced at all others of Danisco's factories, the acetic- and citric acids were tested at one factory.

Facts on Nitric Acid

Formula: HNO_3

Nitric acid is a strong acid that reacts with most metals. Therefore it is often used in metallurgic processes and in the refining of metals etc. In addition, it is a strong oxidizer and those two features combined makes it suitable for cleaning equipments and containers in the food industry. Iron as well as aluminium both stands up to nitric acid because a protective layer of oxides is formed on the surface of the metal, and this protects it from being attacked by the acid.

100% nitric acid, also called fuming nitric acid, releases the toxic gas, NO2, and it reacts strongly with almost any organic material. Sometimes this process even starts a fire.

Combustion of coal and oil releases a mixture of nitrogen oxides, which then react with water to form nitric acid. Nitric acid is thus one of the chemical compounds found in acid rain, and it is partly responsible for the acidification of soil and water.

Nitric acid is on the List of Dangerous Substances, classified as corrosive.

Results and Experiences

In general, the employees have been pleased with the substitution project. They have not been in direct contact with the substitutes, but still it is always good to know that what they are working with is not dangerous or harmful. "*But it has been somewhat difficult to explain to them that the chemicals they have been working with for so long are not the best*." Most people are rather comfortable with well-known territories. Some of the production workers were worried that the new chemicals would not be as good – they feared that the machinery would be calcified. But after the new chemicals were tested at some old machines, they became convinced that they were as effective as nitric acid.

From an economic point of view, the substitution has not increased the production expenses.

"*We try to make sure that people working at different departments know what is going on at the other departments*." Nakskov Sugar can recommend others to substitute. Once the employees are informed about the reasons for substitutions, they are usually happy to be part of the projects.

"*The project has made no difference to our costumers. They ask a few questions – but they can also read about the whole thing in our annual report*."

Nakskov Sugar, as well as almost all the employees, has been pleased with the project. The substitution has helped Nakskov Sugar meet the standards of Danisco's own environmental regulations.

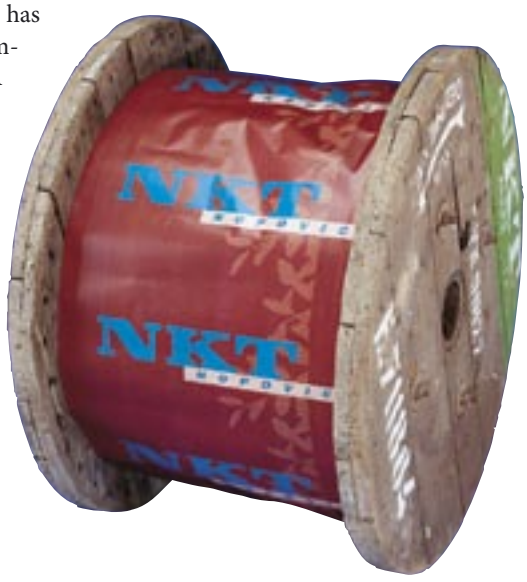
5.5 nkt-cables

An interview with Jens Thiesen; Director of environmental issues.

nkt-cables a/s is the Danish department of **nkt-cables group**, which again is owned by NKT Holding A/S. The head office is placed in Köln and they own production companies in Germany, Poland, Czech Republic, China and Denmark. Different production companies specialise in different productions. Three of **nkt-cables'** factories are located in Asnæs in Denmark. One of these produces flexible wiring systems primarily for the OEM (Original Equipment Manufactures) market; that is producers of appliances such as radios, fridges, curling tongs, cookers, pumps etc. Another factory produces cable installation primarily for the installation market. And the third factory produces low and medium voltage cables for utility suppliers.

All of the **nkt-cables group's** factories have implemented an environmental management system according to ISO 14001. The management system includes health, safety and environmental issues. NKT has environmental policies which must be known to and followed by all employees. Environmental concerns influence product developments the same way as other concerns. Environmental risks are assessed before new productions are started, new raw materials and changes in the production process included. NKT does not produce eco-labelled products since there has so far not been any demand for this. "*As far as I am aware, there has not been set any criteria for eco-labelled products yet. We doubt that such a label will make any difference to our sales figure the way the market looks at the moment. Therefore we have not made much of an effort to have such criteria formulated by the Swan or the Flower. On the other hand, we do believe that our halogen-free series would meet these criteria if they were to be formulated in the future.*"

NKT owns a recycling plant in Stenlille (Denmark). Here all types of cable waste are treated. The company has developed a patented method for chemical reforming of PVC waste to calcium chloride and coke. A few years ago this method was sold to RGS 90 who is about to use it on a plant in Stigsnæs. In 1993 NTK Holding formulated its own environmental policy emphasising the use of purer technology and sustainability. Subsequently, the method was introduced at all subsidiary companies – **nkt-cables** included. The policy stresses the importance of an environmental assessment of all raw materials used in the production. The development of NOPOVIC® is a good example of that. NOPOVIC® means '**no po**ly**vi**nyl**c**hloride.'



Substitution of lead stabilised phthalate-containing PVC

PVC stabilised by lead and softened by phthalates is the most commonly used isolating material for installation cables. This is due to this product's technical and fire retarding qualities. As part of an agreement with former Minister of the Environment Lone Dybkjær, **nkt-cables** began to eliminate lead in their production in the 1980s. In 1993 nkt-cables was able to present the world's first lead-free PVC installation cables. The agreement was in 2001 followed by a ban on cables containing lead. Concurrent to this elimination process, fire-retarding materials were developed as alternatives to PVC used in installation cables and in flexible wires. The substitution process was started because the media picked up and reported on the hazardous effects of PVC and phthalates and on the dangers associated with PVC when exposed to fire. "*The press was informing people about PVC and phthalates and about their hazardous effects. And as soon as NKT realised that these materials could have harmful impacts on the environment, they decided to try to develop alternatives*". For safety reasons, the starting point of the substitution was navy and offshore cables. During a fire, PVC cables will produce dense, black smoke by which the visibility will be weakened. After 10 years of developments, the first cables were introduced into the market in 1995. They are considerably more expensive compared to the old PVC cables, and therefore they were never really a success. It has to be realised that the plastic material used to produce the cables is pressed through a 'meat processor', and if the viscosity is high, more power is needed in order to press the material through the machine. The turning point in the development came after changes were made to the recipes by which the viscosity was lowered without changing the quality of the product. The capacity level has gone up whilst the energy use has gone down. The plastic is developed by **nkt-cables** together with one of the suppliers of the plastic raw materials. The company decided to avoid halogens and phthalates completely in their cable production. In 2001, the entire wire and cable system was converted into a phthalate- and halogen-free version. Only a few products still contain the PVC-material for competitive reasons. "*The market did not react the way we had expected it to. Regarding the OEM section, most of our costumers did not want the PVC-free products since some basic properties had been changed resulting in rejection of the nkt cables in many cases. The turn-over was so low that we decided to re-introduce some of the products containing PVC. In 2004, the substitution of PVC reached a level of more than 40 %.*"

Why nkt-cables substituted

The good reasons for substitution of lead stabilised, phthalate containing PVC are as follows:

- To avoid an annual use of 2.500 tonnes phthalates and 10,000 tonnes PVC containing approximately 100 tonnes lead compounds. And over time, to having to dispose of from 10,000 - 15,000 wasted PVC from cables.

- PVC is made from vinylchloride which may cause cancer. PVC is softened by phthalates, of which the most commonly used is DEHP. "*Today only the phthalates: DINP and DIDP are used. They need not be labelled and according to a risk assessment carried out by the Institute for Health and Consumer Protection within the EU, they are considered to be relatively harmless. However they should not be used in toys which may end up in small children's mouths*." Moreover, PVC containing cables will cause problems when they have to be disposed of. PVC, which cannot be re-cycled, must be stored. Even if we incinerated it, it would create huge amounts of incineration waste, which needed to be deposited at special, selected sites. For these reasons, local incineration plants are reluctant to accept PVC together with other items of waste. The new cable type: NOPOVIC® is based on a mixture of halogen-free polymers such as PE, PP and EVA copolymers with added non-flammable minerals like magnesium and aluminium hydrates. The energy consumption is still higher for NOPOVIC® cables than for PVC cables, however this is gradually changing. About 300 kWh/tonne extra energy is used – corresponding to 5 -6 % of the total energy consumption during the production. With the current level of substitution at 40%, a cost increase at the level of 70,000 Euro per year has been noted. In return, the substitution has resulted in less pressure on the country's deposits for toxic waste, since waste amounts of NOPOVIC® can be delivered to and accepted by the incineration plants where the heat created can be utilised.
- In situations of fire, NOPOVIC® is a both safer and better material for human health compared to PVC cables. NOPOVIC® does not release any corrosive vapours, which in turn will be rise to formation of hydrochloric acid. Instead, only a light smoke is produced. This entails greater visibility which then permits better conditions for possible escapes and rescues. All types of smoke, including also the smoke from NOPOVIC is dangerous. But the smoke from NOPOVIC is no more dangerous than that from any 'ordinary' fire and, especially, since NOPOVIC® does not create any corrosive vapours, there will be less damage done to buildings and equipments. Most insurance companies are unaware of these fact, and therefore there is no extra charge if PVC cables are used. "*This is not something we ask our costumers*" (Tryg Forsikring – Danish insurance company).

The Substitution is an Investment

"*Our employees have expressed different opinions towards the substitution. Some have said that the idea was good; others have said that it wasn't. The difference of opinion is based on the fact that a study has shown that small amounts of DEHP released from cables make no difference, whilst other studies have shown that they do*."

The product development has resulted in a need for larger compound facilities in order to develop and produce halogen-free compounds. The cost of this amounts to 1.2 million Euro. Moreover, the rebuilding of the lab has cost the company another 140,000 Euro. Several man-years were spent in the lab developing the new product. "*The substitution has been expensive considering the rebuilding and the many man hours spent*." In 2002, NKT-cables received an

EU environmental award in the category 'Green products' recognising their work on PVC-free and halogen-free products (NOPOVIC®).

The use of NOPOVIC® plastic has been increased from 164 tonnes in 1997 to 3,375 in 2004. This figure is expected to rise even more – to around 15,000 tonnes per year – when the entire Danish market is using the new product. "*To us the process has been both exiting and challenging, and we would recommend other companies to do the same. I do not know if I would want to call it a success since we have not sold nearly as many as hoped. We have received awards and recognition, but sales haven't gone up accordingly. When both professionals and private consumers build houses they want to save money, and therefore they buy cables containing PVC. It is difficult to substitute when the rest of society doesn't want to play along. After all, we need to be able to sell the products*."

Taxes on PVC and phthalates have helped lessen the difference in prices compared to NOPOVIC® cables. The most important breakthrough came from the development process. Judging from the lead-free PVC, which resulted in a ban on lead in PVC 10 years after NKT had introduced the lead-free product, we can only hope PVC in cables will be banned in a ten years time. "*The tax on PVC is a good thing. It has made prices on PVC-free cables comparable to those of PVC cables. Personally, I think that the hazardous effects of PVC and phthalates have been exaggerated by the press. The cables will last for many years. For PVC cables there are problems with the disposal, whilst there are problems with the high level of energy consumption when we are avoiding the use of halogen. There are pros and cons – no matter which type is considered. Surely, cables without PVC are safer when used in tall buildings. But it is not really necessary to use PVC-free cables in family houses*". This is because it is much quicker to escape from an ordinary family house during a fire, and less toxic smoke will be inhaled. Therefore NOPOVIC® is safer in buildings with few escape routes (tunnels or multiple storey buildings), in buildings where elderly or less mobile people live or in buildings where valuable electronics are kept since hydrogen chloride will damage electronics completely.

The project is relevant to all of Europe. Potentially, NOPOVIC® may help develop other alternatives to PVC. "A*t the same time, it is important to notice that it is important to Denmark to show the profile of being a frontrunner on an issue where the rest of Europe can be expected to follow in the coming years*".

NKT now has a greener image. They are now known to be a company that cares about the environment. It is unknown whether they have gained any new costumers as a result of the substitution.

Facts on Plastic

Plastics are polymers. All plastic types are primarily made of carbon and hydrogen – and sometimes chlorine. Plastics are defined as organic materials made of macromolecules – polymer chains of monomers.

$$(CH_2 - CH)_n$$
$$\quad\quad |$$
$$\quad\quad X$$

The X in the formular indicates: Hydrogen (H), Chlorine (Cl) or methyl (CH3) according to the type of plastics, namely Polyethylene (PE), Polyvinylchloride (PVC) or Polypropylene (PP), respectively. These are produced either by processing natural products or they are synthesised from primary substances of oil, natural gasses or coal.

There are three types of plastics:

1) **Thermoplasts**. This name refers to the fact that the materials become plastic when heated and hard again when cooled down. This quality is used in the manufacturing of plastic products, as the material is heated, molded and subsequently cooled down. Accordingly, thermoplast waste and old products can be melted and re-used. Themoplasts make up 85% of the total plastics consumption. Examples of thermoplasts are: PE (polyethene), PP (polypropylene), PVC (polyvinylchloride), PS (polystyrene) and EVA (ethylvinylacetate)
2) **Duroplasts**. Unlike thermoplasts, duroplasts cannot be melted once it has been molded and hardened. And therefore it cannot be re-used. In stead, duroplasts will, when heated at high temperatures, be charred.
3) **Elasts** are characterised by having macromolecules bound in such a way that, when affected by a light force, the material is capable of being deformed several hundred percent and resume to its original form afterwards. This material is, for example, used in sponges.

Plastic raw materials, which are delivered by the supplier to the plastics processing plant, usually contain several different substances – additives – whose purposes are to make the molding process easier and to improve the final product. The additives assist in the processing of the plastic end product and make it possible to produce tailor-made plastic products. Some of the most important additives are: **Surface treatments** give the material extra strength. **Plasticizers** make the materials flexible.

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Colour pigments give it colour. **Stabilizers** protect against ultra-violet radiation and thermic degradation. **Antistatics** prevent static electricity. **Fire-retardants** retard fire. And **fillers for plastics** make the material stretch longer – these could be chalk or dolomite.

PVC is a common form of thermoplast. It consists of carbon, hydrogen and chlorine. It is a hard form of plastic and therefore a softener needs to be added before it can be molded. In this way, the created plastic material is given strength and flexibility, and at the same time it becomes long-lived and cheaper. World wide, PVC makes up 20% of the total plastic consumption. In Denmark, it makes up 15% of the total consumption. There are no Danish manufacturers of raw PVC.

PVC causes several different environmental problems. When burned, hydrochloric acid is released; and subsequently this needs to be neutralised using a considerable amount of alkaline material, e.g. chalk. Heavy metals contained in the PVC (lead and cadmium) will, in the course of the incineration process, be concentrated in the solid residues. PVC contains up to approximately 50% chlorine and several additives (as mentioned above) to which different environmental issues are related. The waste product weighs more or less the same as the original PVC. And it contains a large amount of chalk, which makes it unstable, and therefore it must be deposited in a special manner. Moreover, it contains heavy metals and organic toxins – such as dioxin. PVC-containing waste, which is incinerated, may contribute to the creation of dioxin. However, to which extent the creation of dioxin is affected by the content of chlorine in the PVC remains unclear, considering that chlorine will always be present in mixed waste material – in wasted food, wood etc.

Alternatives to PVC are PE, PP and EVA etc. PE makes up around 45% of the total plastics consumption in Denmark, whereas PP makes up around 15%. If we compare the different plastic materials in terms of energy use during the manufacturing processes and pollution during the production and waste removal processes, the result will be that PE and PP are to be preferred. None of them have seriously damaging effects on the environment beyond the oil usage and the release of CO2, which is part and parcel of all plastic products. This means that only water and CO2 are released during a total combustion. This presupposes that the products in question are without additives.

MS-polymers (Modified Silane Polymer) stand out from the plastic types mentioned above by having silicon as one of their main elements. They are mainly used in fillers and they are characterised by being free from isocyanate and silicone (polymers based on chloro-silane), of which especially isocyanate (monomers contained in polyurethane) is severely hazardous to human health. MS-polymers have features that combines those of silicone and polyurethane.

5.6 Fujitsu Siemens Computers

An interview with Thomas Mardahl; Product Manager and Fujitsu's production company in Germany.

Fujitsu Siemens Computers is the leading European IT provider with a portfolio stretching from notebooks through to total enterprise solutions. The company employs approximately 7.000 people. Fujitsu Siemens was created in 1999 through the fusion Siemens AG and Fujitsu Computers Ltd. Production and development units are based in Germany and the US, and the company is strongly represented in all its key markets across Europe, the Middle East and Africa. Fujitsu Siemens has a dedicated department for environmental affairs, dealing with issues of waste, recycling and other related environmental issues. This department is located in Germany. The company has a similar department for Nordic environmental issues based in Sweden. Germany – followed by the Nordic countries – is Fujitsu Siemens' most lucrative market. Therefore, environmental issues are highly prioritised in these countries. Products sold in Germany and the Nordic countries carry eco-labels. Fujitsu Siemens has implemented environmental management and accounting. In Denmark, they are certified according to ISO 14000.

Fujitsu Siemens is working hard on keeping the position as Europe's leading provider of 'green' computers. The company invented the screen saver. Environmental protection is an integral part of their philosophy. This means that they need to follow certain rules when new products are developed; for instance, they do not allow for any of their products to contain hazardous chemical substances.

The Substitution Process

In Germany and the Nordic countries a sudden demand for environmentally friendly computers appeared. At the same time, Fujitsu Siemens wanted a 'green'

image. Accordingly, they embarked on a substitution project and started developing the Green SCENIC PC. "*We wanted to present the company as the one with the most environmentally friendly PCs. We meet the demands of the market – and then takes it one step further*" (Thomas Mardahl). Fujitsu Siemens looked into which problematic substances they needed to remove and into how this might be done. As an example, they reduced the computer's content of lead from 12g to 3g. Lead was substituted with tin solder. On a yearly basis, this means a reduction of lead by 10 tonnes; and in 2006, this figure is expected to rise to around 25 tonnes pr. year. Besides, the company has removed PVC, cadmium and mercury, and – where possible – they have removed the brominated flame-retardants from the SCENIC PC. They examined the processes and found that lead in tin solder was unnecessary. And similarly, they discovered that the washing of the print cards, which brought about discarded substances, was unnecessary. So of course, they eliminated this part of the process.

The Fujitsu Siemens Green Line computers were launched in the beginning of 2002. The Green Line series is more expensive, but then these computers do hold many improved features. To find out if anything could be substituted, the Green PC's were examined from A to Z. The manual is now printed on recycled paper, no EPS-plastics (expanded polystyrene) is used and only re-cycled wrapping paper is used. Moreover, it is possible to return old computers to the factory in Germany for recycling. 90 percent of a SCENIC PC can be reused, whereas the remaining 10 percent are not yet recyclable. The SCENIC computer meet the requirements of the eco-labels: The German Blue Angel and the Nordic Swan label. This result is mainly down to the idea of life cycle assessments, involving a thorough assessment of all aspects of the production including choice of materials, production processes, means of transport, recyclability of all parts of the computer etc. The materials used are assessed according to environmental risks relating to their use, reuse and waste removal. Consequentially, the use of dangerous materials has been minimised. Not only is that good for the environment, it is also healthier for the employees. SCENIC computers only contain plastic parts that are labelled for recycling. And the energy spending during the production processes is now down to a minimum. The majority of the production companies have equipments, which can reuse the heat from the ventilation. Furthermore, Freon (CFCs, HCFCs, HFCs), propelling the heat exchangers, has been replaced by ammonia, and now they use powder coating, which eliminates the amount of solvents, wastewater and paint sludge. The packaging materials are reduced to a minimum. This, in turn, minimises the load that needs to be transported; and one truckload can hold more units. Fujitsu Siemens carries out the dismounting and re-cycling of the computers at their own industrial unit. "*The entire computer is examined. Today, consumers demand computers in the colours silver or black, but it is not possible for us to meet these demands, as that would involve using problematic substances. We think of everything right down to the last detail. The on/off button had to be painted with lacquers not recyclable, as otherwise it would not stay on for long*" (Thomas Mardahl). The development of new computers is fast growing, and each year more and more computers are discarded. The Green PC is an attempt to solve this problem; it is a computer almost harmless to the environment, and it is sold at a competitive

price. The main focus has been on stationary computers and computer screens, as they are sold in greater quantities compared to laptops. Besides, the amount of material necessary to produce a stationary computer exceeds that which is needed for a laptop computer. Hence, one stationary computer contains several kilos extra material, which need to be recycled and which cannot contain hazardous substances.

The developing process has run for a period of more that three years, and they continue the substitution. "*It is an on-going process, and there is a tendency towards focussing more and more on the environment. At the moment, a lot of attention is given to energy saving. These tendencies suit us just fine*" (Thomas Mardahl).

Economics and Image

The substitution process has been a time consuming and costly affair. The first computers were sold at a rather high price, but after some of the expenses had been recovered, it was possible to lower the price a little. The costs of the substitution have been considerable. "*There have been extraordinary costs. We have, for instance, reduced the content of lead from 12g to 3g. To do that, we had to change the production process and that was expensive. Of course, it is expensive – and the costumers will have to pay the extra price. But it is also an investment. The costumers might say, instead of paying 20 Euro extra, they now only want to pay 10 Euro, and then we have to pay the remaining 10 Euro. You always have to consider carefully how much you really want to fight for the environment – as this may end up being very expensive. One thing we cannot allow to happen, is that people stop buying our products because they are too expensive. We cannot take for granted our costumer's desire for environmentally friendly products*" (Thomas Mardahl). It takes a lot to substitute. Many people need to get involved each time something new comes along.

The consumer's reluctance to pay extra for an eco-labelled computer has been a problem. "*Maybe part of the explanation is that most buyers are appraised according to whether or not they can comply with their budgets. That is a challenge. And likewise, the public sector, which has been an eager buyer of eco-friendly products, has now become more focussed on budgets*"(Thomas Madahl). Fujitsu Siemens has tried to convince public institutions to buy the Green PCs by offering to send a reporter to write about them, as buyers of environmentally friendly computers.

Fujitsu Siemens wants to stand out as the green alternative on the computer market. "*I don't think anyone is in doubt that we produce the most environmentally friendly computer on the market. But now it appears as if the competition has become tougher. The consumers are well aware that we have the 'greenest' product, but some still choose not to buy. But luckily, others do choose to buy our product. In fact, demands for eco-friendly computers are rising*" (Thomas Mardahl). Fujitsu Siemens' green image makes the company different from other computer manufacturers.

Results, Experiences and Challenges

Fujitsu Siemens replaced their original suppliers during the substitution project. They keep establishing new requirements for their suppliers. At the moment, they are working on a project with INTL. INTL has recently produced a 'green' component for PCs which contributed to Fujitsu Siemens' successful reduction of the content of lead in their computers. "*When a large company like INTL begins to produce 'green' components it is a clear sign that demands for eco-friendly products are rising. A general positive attitude in society towards protecting the environment is a good tendency. It is strongest in Germany and the Nordic countries. But this is not quite good enough, if we are talking Europe- and world market production*" (Thomas Mardahl). Fujitsu Siemens is now as close as possible to have made a computer completely free from hazardous substances. "*The substitution has made us aware of other factors such as the energy consumption. This will be the next thing we need to consider. We would like for this to be reduced even further*" (The German production company).

In the future, Fujitsu Siemens plans to look into the production of laptops, as the sales figures for these are rising. Yet since stationary computers are so much heavier, if we are counting kilos, the sales figures for stationary computers still exceed those for laptops many times. "*Our laptops are eco-friendly. Everything it was possible to remove without extra costs has been removed. This means, that mercury contained in the screens has not been removed. It is, however, possible to have the mercury phased out, but we have decided not to, as it would involve extra costs, and, at the moment, the consumers are not willing to pay extra. It is the old question of which came first – the chicken or the egg. If all computer manufactures were required to phase out all mercury in their products, it would be a different story. It would not be possible for us to do it, if everyone else didn't – we would not be able to compete on the price*" (Thomas Mardahl). Mercury and lead in laptop computers are the main reasons why they do not meet the requirements of the Swan label. Nor is it possible to produce motherboards without brominated flame-retardants, unless you increase the costs considerably. "*It would make no sense to introduce Swan-labelled computers to, say, the Italian market where people cannot relate to this label. And when the Flower becomes as well known in the Nordic countries as the Swan is today, we plan to simply use the Flower from then on*" (Thomas Mardahl). From October 2001, selected Fujitsu Siemens products were allowed to carry the Swan label and the GEEA label. "*It annoys me a little that our laptops do not qualify for the Swan label. We have done everything possible within reasonable economic limits, and still they do not qualify. Of course, the requirements of the Swan label must be high – but not unattainable*" (Thomas Mardahl).

Fujitsu Siemens has not received many computers for disposal yet, as most people are not aware of the arrangement. Most worn-out computers are transported to the Far East or end up as waste on a combustion plant. It is not easy to get rid of old computers and it is expensive too. But soon we will see a new law, which states that all public institutions must return old worn-out computers to the manufacturing company (came into force by 1 January 2006). "*It would be impossible for us to accept all worn-out computers without adding our costs*

to the whole sale price. Is that realistic? If all computer manufactures did the same, all computers could be priced the same. This demand needs to come from the authorities" (Thomas Mardahl). More that 600.000 PCs are sold on a yearly basis in Denmark. This leads to many tons of computer waste.

In general, the employees at Fujitsu Siemens have accepted the substitution. "*It is a morally sound message to send, and therefore most of them were pleased with it. It must be a good thing for those working on the machine that they now no longer are working with dangerous substances*" (Thomas Mardahl). The substitution has been a great challenge for the production and development unit in Germany. Almost everything is possible, but if the prices have to stay at the right level, it is sometimes necessary to compromise. The sales reps have not been too exited, as it is always difficult to convince costumers to buy a product that is relatively more expensive. "*I guess you could say that we have had a love-hate relationship with the green computers. We would not be without it. It is such a strong message to send, and it gives us advantages in competition. On the other hand, it is tiresome to always have to justify the surplus price. Sometime it is hard for us to understand why the costumers cannot see that the protection of the environment is important, and that they will have to pay more to contribute to this. Then it is great to deal with those who do understand this. It makes sense to buy a computer, which, for the most part, can be reused. Or you can tell your employees that the computer they are working on does not contain brominated flame-retardants*" (Thomas Mardahl).

"*I would like to recommend others to substitute from an environmental point of view*" (Germany). Costumers seem to like the product and some are even willing to pay extra to get a Green PC. All in all, Fujitsu Siemens is pleased with the substitution. "*In a way, I think we are obligated to do it – honestly speaking. It ought to be the responsibility of all of us. But it can be a little difficult to relate to something that will not come into effect until 20-30 years from now. That might be the reason why so little is done*" (Thomas Mardahl).

Facts on heavy metals

Heavy metals are found in nature. They are generally defined as metals with a specific density higher than 5g/cm_3, but a most often seen characteristic is that they are metals which are hazardous even in small doses. The problem with heavy metals is that most are toxic and not biodegradable, and they may accumulate up the food chain in the fatty tissue or in organs of humans and animals. Heavy metals may hamper recycling of waste products such as slag, fly ash, residues from gas cleaning, sludge and compost. Three of the most important, toxic heavy metals are described below. Other hazardous metals are arsenic, nickel and chromium.

Lead (Pb)
Of all the heavy metals lead is the one most commonly found in nature. Lead binds easily to soil and therefore it is possible to find soils which still show traces of past lead contamination. In larger cities, we see an extensive, diffuse lead pollution. Especially, since up until the mid 1980s petrol contained organic lead compounds. Lead may be found in many different products: electronics, electric components, roof tiles etc.

Lead is absorbed into the human body if we are exposed to lead via the air, dust or our food. Lead is a toxic substance affecting the nervous system. High concentrations of lead cause severe deterioration of learning abilities and changes in the reproductive system. It has recently been discovered that even very small concentrations of lead may cause child learning disabilities. Lead will have both acute and chronic toxic effects on vegetation, animals and micro-organisms.

Lead and lead compounds are classified as CMR substances belonging to the categories 1 and 2. In Denmark it is illegal to use lead in consumer products, and from September 2004 it became illegal as a constituent in cosmetics in the EU. Lead is regulated by executive order no 1012 of November 13, 2003 on the ban on sales and import of lead-containing products. There are certain exceptions like lead accumulators. Lead may still be a problem in waste because these may contain old traces of the substance.

Cadmium (Cd)
Cadmium is found in nature in relatively small quantities. The metal can be found in products such as electric components, plastics, batteries, accumulators, colour pigments etc.

Cadmium and cadmium-containing chemicals may have acute toxic effects on both humans and animals. Moreover, there are good reasons to fear cadmium since it may accumulate in the human body – especially in the kidneys. Other long-term effects are changes in the reproductive system, reduced growth, and kidney and liver diseases. Furthermore, cadmium prevents us from absorbing important and necessary substances.

Most cadmium compounds are found on the List of Dangerous Substances. It is illegal to use cadmium in Denmark with a few exceptions (batteries included). Cadmium and cadmium dioxide are presently undergoing risk assessments within the EU. This is included in the EU resolution no 2455/2001/EC of November 20, 2001.[34]

Mercury (Hg)
Mercury is found in products such as batteries, dental fillings, fluorescent tubes, electrical switches and computers. Mercury is easily absorbed into the body and it affects the brain and cause visual disorders, motor and balance disabilities. Furthermore, mercury may affect embryos and in severe cases it may lead to brain damages in the newborn child. Creatures at the top end of the food chain will contain most mercury due to the fact that the amount of the substance is accumulated up the food chain. Therefore it is recommended that pregnant women refrain from eating certain kinds of fish (large predatory fish) or fish caught in certain, relatively contaminated waterways – e.g. the Baltic Sea and some freshwater systems in Scandinavia.

Mercury and mercury compounds are on the List of Dangerous Chemicals. Mercury is contained on the EU resolution no 2455/2001/EC of November 20, 2001. There is a ban on the use of mercury in Denmark– with a few exceptions: the substance is, for instance, allowed in dental fillings.

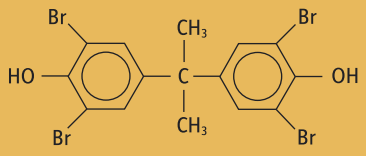
34 Substances for which the emissions or losses must be stopped or phased out 20 years after the adoption of the directive, at the latest, with the final goal to achieve concentrations in the marine environment near the natural background concentration for naturally occurring chemicals and close to zero for synthetic, manmade chemicals (European Parliament and Council decision no. 2455/2001/EC of 20 November 2001 on the adoption of a list of priority substances for water policy and on amendment of directive 2000/60/EC)

Facts on brominated flame-retardants

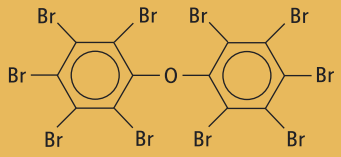
Brominated flame-retardants belong to a group of substances used to hinder or delay fire in electronic equipment, building materials, furniture etc. They are organic compounds containing bromine and they are often formed by two linked phenyl rings with variable numbers of bromine atoms attached. In electronic equipments the brominated flame-retardants are found in compartment, printing plates and switches.

There are around 40 different brominated flame-retardants. The most common groups are as follows:

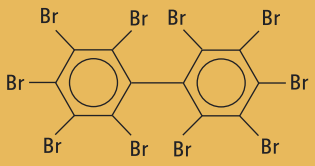
TBBPA (Tetrabromobisphenol A)



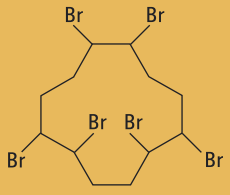
PBDE (Polybrominated diphenylethers)



PBB (Polybrominated biphenyls)



HBCD (Hexabromine cyclododecan)



The most problematic groups are PBB and PBDE and the most commonly used are deca-BDE (decabromodiphenylether), belonging to the group PBDE, and TBBPA.

Brominated flame-retardants may either become a part of the material they are protecting from fire through chemical reactions, or the substances are mixed with the material as an independent component - an additive. They are easier released from the material when they are used as additives and not chemically bound.

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When the products are produced, used or disposed of, the hazardous substances may be released and subsequently inhaled by humans or enter into the environment via rain or dust. Brominated flame-retardants are – in various degrees – slowly degradable and will never disappear completely after they have entered into the human body or the environment.

Based on animal testing results, researchers suspect that the substances may affect embryo formation and the reproduction system, that they may cause cancer and that they affect the function of the thyroxine. The thyroxine helps regulate growth and development of embryos and of the newborn. Its structure is quite similar to that of PBDE.

Several American, Swedish and Japanese studies have detected brominated flame-retardants in breast milk. Especially high concentrations were found in breast milk from American women. Brominated flame-retardants were also found in animals – e.g. in whales. In their mobility and distribution patterns in environment brominated flame-retardants are comparable to the insecticide DDT and to the synthetic oil and plasticiser PCB. Like DDT and PCB, they consist of linked phenyl rings to which halogen atoms are attached – only bromine instead of chlorine atoms. Both DDT and PCB have harmful effects on humans and on the environment, they both degrade very slowly and they are stored in fatty tissue and accumulated in animals at the top end of the food chain (humans included) – just like brominated flame-retardants.

Other less used flame-retardants are: vinyl bromide that may cause cancer, and 2,4,6 – tribromophenol that may affect the liver and cause damages to embryos.

Penta-BDE (penta-bromidediphenylether) is classified as irritant, harmful and as environmentally hazardous. The substance has been – like octa-BDE (octa-bromidediphenylether) - banned in the EU. Furthermore, deca-BDE and PBB are included in the EU directive no 2002/95/EC banning their uses in electronic and electric products as from July 1st , 2006. Presently, however, it is uncertain whether deca-BDE will be included in this ban. The industry has voluntarily removed PBB from the market. Deca-BDE, TBBPA and HBCD is undergoing risk assessments within the EU.

5.7 Poul E. Meier

An interview with Poul E. Meier, Director.

Poul E. Meier ApS. is a small, independent company with just one employee. The company was founded in 1992 and delivers innovative and creative solutions related to environmentally friendly constructions and joinings. The company may also be consulted for advice on constructions using glue and adhesive substances. Their clientele stretches from electronics and instrument constructions to power stations and buildings. Administration and development are done from home. Poul-E Meier is a mechanical engineer and he has, for the entire duration of his career, been working on substitutions and developments.

The Substitution Process

In 1999, after having mounted a chimney pot on a weekend cottage, Poul-E Meier conceived the idea of substituting lead in roofing felts. "*I suddenly got puzzled by lead's technical and environmental qualities. I found it a little strange that moss is unable to thrive beside it.*" Moreover, the roofing felts must be ordered according to the angle of the roof and you need to be careful with the joinings, not to break it. And the result is not very pretty.

"*It must be possible to do this a better way, I thought. Lead is no good – not for the environment and it is not easy to work with.*"

Later that year, Poul-E Meier was contacted by Teknologisk Partnerskab (Technological Partnership). They asked for help to find alternatives to lead found in roofing felts. "*This was a challenge, I agreed to help and therefore got the assignment.*"

Poul-E Meier's immediate idea was to solve the problem with some glue and some chicken wire. He began by making various mock-ups and by testing some of his ideas. Subsequently, he contacted different companies. The first few companies, which had already been contacted by Teknologisk Partnerskab, were only interested in buying existing products. But in the end, Poul-E Meier succeeded in finding a company willing to participate in a development project. This company was Exhausto A/S, a company that produces ventilations and chimney fans. They use roofing felts, as when they sell their systems they also sell pipes, which go through the roof. Exhausto had not been able to find a product which suited their requirements, so they wanted to contribute to the project by formulating their own requirements to the product and by running the necessary tests. "*At first, I thought they might want to actually produce the product – but that turned out not to be the case. Then I got an idea. Lead is contained in roofing plates almost everywhere, therefore this*

project must be of wider interest." Poul-E Meier then presented his ideas to the Danish Environmental Protection Agency. The EPA thought the idea was good and they recommended him to apply for funding through the 'Renere Produkt" (Purer Products) programme. Poul-E Meier received positive feedback on his application, as the EPA was willing to back up the project by providing financial support and by providing expert advice.

A team was formed consisting of Exhausto A/S, COWI A/S and the EPA. The main responsibility of this team was to assess all suggestions and give Poul-E Meier feedback. Poul-E Meier also received guidance from Technological Information Center in Hillerød. Now that he had financial backup, the idea connected with chicken wire was taken one step further, as now the same idea involved expanded metal grid and different types of joint fillers. Which type of filler is chosen makes a huge difference. Some of them contain phthalates. "*And I would like to get rid of those as well. It is important to me to create a product improved in every way. I wanted an improved working environment; a product that was easy to work with, and I wanted it to be nice to look at. And there ought to be no problems discarding the product*." When roofing tiles containing lead are turned into waste, the lead is not treated separately, as each tile only contain a small amount of lead. Therefore it is important that the product is environmentally friendly.

Testing was part of the process. Poul-E Meier wanted to make sure that the new product was resistant to all types of weather; that the product was flexible, could be stretched and that it could be mounted at various surfaces. Exhausto took care of these tests. "*When I was content with the result, the product was tested by experts and technicians at Exhausto A/S once again. The Danish Building Research Institute finished the test series by sending the product through the so-called 'torture chamber' – a severely thorough test method*."

The product 'Perform' was the final result of the development process. It is composed of a strong aluminium grid embedded in rubber/plastic. The plastic is a MS polymer. A silan-modified polymer often used to create flexibility in glue products and joint fillers. After the hardening process, the product becomes rubber-like. MS polymers has MAL-code is: 00-1 or 0-1, which used on water based plastic paint for indoor use. Perform seems to be able to meet the requirements of all types of roofing tiles, and compared to lead, its qualities are better. Perform may be disposed of the same way as ordinary building site waste. Aluminium is a limited resource and the quantity of energy used at its manufacturing is high. Therefore, re-cycling seems very relevant in connection with Perform. Perform contains no fire-retardants. Perform may be shaped in the same manner as lead, and it is possible to butt without any visible lumps.

"*When I first sat out to perform the substitution, the main objective was to substitute lead. But once the whole thing got started, we became focussed on phthalates, and, subsequently, they were substituted as well. Early in the process, I discovered that aluminium would be a suitable substitute. I saw no problems with this product of high technicality. It is easy to re-use, as Perform can be*

burned off, and it is easy to separate". As the new product was easy to copy, it was necessary to apply for a patent.

The development process went according to plan. In order to make sure the best possible product was introduced into the market, it was necessary to examine the products of the competition. Poul-E Meier was surprised to learn that it was not easy to find a producer. Luckily, Technological Institute, Department for Inventions and Creativity was able to help. In 2002, an introduction meeting was held for potential producers, among which was Anders Kjær Jørgensen who was interested in becoming part of the project. After a couple of months, the licencing contract was signed and the company Robert & Kjær ApS was formed. Robert & Kjær ApS would then produce and sell Perform. It took one year longer than expected to find a producer for Perform and, consequently, a minor loss.

Results

Perform is expensive compared to lead, but priced more or less the same as the other alternatives. The pricing needs to be viewed in relation to the number of

man-hours. It takes three times as long to beat out lead in comparison to Perform. The total mounting time is halved. When discussing prices, the number of man-hours spent is important. Therefore it is not necessarily more expensive to use Perform. "*I would love to advertise Perform as an environmentally friendly product, but the truth is, I do not know how big the effect of this substitution is on the environment*." The plumbing industry has shown a great deal of interest in Perform. The product is sold to all plumbing wholesalers and to some timber merchants. "*At the plumbing wholesalers, the product is the best selling of its kind*."

"*At one point during the development process, a date was set as to when all lead should be phased out of roofing tiles. The date was only applicable to new buildings. Maybe this had something to do with the fact that now alternatives, of which mine is one, are available on the market*." The date was December 1st, 2002. This means that negative effects on the environment caused by lead from roofing tiles will be minimised. Regarding the working environment, we will see an improvement caused by Perform as it is glued by means of MS polymers, and lead soldering is avoided.

Perform carries no eco-labels and "*there exists no eco-labelled roofing tile. I have considered signing up for a label, but I imagine that only very few builders notice the labels. Large companies do consider environmental issues, but I doubt that the small builder bother about these labels, if they only use Perform once a month*."

According to Poul-E Meier, the substitution process has been very exiting. "*I want to recommend others to do the same. But be careful about the financial aspects, if you are running a small company. Professionally, the substitution, and working on this in conjunction with issues of technicality and use, has been a challenge. In fact, during my entire career, I have been a part of substitution projects*".

Normally, you just use what is at hand. You have used it for many years, and therefore it must be ok. "*The exiting part of a substitution assignment is to find out about the product requirements. How do we make the best product seen in relation to its production, its use and its disposal? It makes people happy to work with products which at the same time serves its purpose well and has no damaging effects on the environment or on human health. There are a lot of aspects to substitution*." Since the Perform projects, Poul-E Meier has received no new assignments of similar kind. Besides working on a few minor projects for the Technological Partnership, he now spend his time on the promotion of and advising on Perform; on keeping himself updated and on trying to find new purposes for Perform.

"*As a technician, it is inspiring for me to suddenly have an expanded network of people working on similar projects. At the moment, I am working on a movie about this subject. The movie is titled: Product Development in Network. I got the idea when AaU (Aalborg University) wanted me to give a speech on develop-*

ment process and networks. My network expanded during the process. Everything runs smoothly when you know the purpose of your work. Just as it always helps, if you are having fun at the same time."

5.8 Dana Lim

An interview with Erik Andersen; responsible for product developments

Dana Lim is one of Denmark's oldest manufactures of glue and joint fillers. The company is owned by Kai Hansen's foundation. In 2001, Dana Lim merged with Åffa A/S, a company that specialises in joint fillers. Today the company employs around 100 people. They have their own laboratory, in which new products are developed. Some products they produce themselves, others they buy. Both categories are required to meet strict environmental and technical demands.

Dana Lim performs green accounting but they have no environmental certificates. They have, nonetheless, strengthened the company by going through the whole process. "*We have chosen not to be certified, as we think an environmental certification has no real value. You need to spend so much time doing all the paper work, time which would be better spent on other things.*"

Dana Lim has an environmental policy, which oblige them to develop and produce products that respect consumer and society demands and expectations of environmentally friendly products and production methods. The company constantly tries to improve the working environment and minimise the strains put on the external environment by improving existing or developing new products and production processes. Moreover, Dana Lim tries to minimise resource spending as well as the generation of wastewater and waste. Dana Lim is very much involved in REACH, the new EU reform on chemicals. Besides, Erik Andersen is a member of FEICA's European Technical Board as the only Dane. Here issues of regulation and interpretation are discussed.

What Dana Lim Substituted

Joint fillers are produced by mixing raw materials such as binders, fillers, pigments and selected additives – preservatives, softeners and surfactants. Dana Lim has already substituted phthalates, oximes and polyurethanes.

When the problems relating to phthalates became known, Dana Lim started substituting their phthalates. The process has been going on for the past 10 years. Besides contributing to the flexibility of the products, the phthalates affect other qualities of the end products. If they are substituted by one of the alternatives – such as the one used in the plastics industry – the quality of the product will change, and therefore these alternatives are not suitable. But after working together with their suppliers, Dana Lim has now found a technical solution with the same qualities as the phthalates-containing products.

Dana Lim has also substituted oximes. The reason for this was that new threshold limit values regarding release of oximes from joint fillers were introduced. There are different types of joint fillers releasing different substances during the process of hardening. Some release acetic acid, some release alcohol and some release oximes. Because of the introduction of new limit values Dana Lim had to make some changes to their products. Dana Lim cooperated with their supplier, who provided raw materials that Dana Lim could use. "*The limit values may*

be changed again in a few months time. And then we will have to start all over again." It took Dana Lim almost a year to meet the new requirements.

Dana Lim has been leading the way when it came to eliminating polyurethane from the joint fillers. Alternatives to the polyurethane are products based on MS polymers. The phase-outs began in the early 1990s, and in most of the cases it was possible to substitute 100%. Some products used for special assignments still contained polyurethane, as it has not been possible to find a suitable alternative. These products are only used by professionals who have received special training.

"*Each time we embark on a substitution project, we intend to take it as far as we possibly can. If it is possible to remove an unwanted substance completely, then this is what we must do. In contrast to many producers of similar products, we produce the entire range of glue products, and that means that it is difficult for us to formulate an environmental policy covering all our products. We want to always be first of the latest developments. When a certain product's characteristics have been defined, it is our job to produce the most environmentally friendly product*." The Danish MAL-code system is a useful tool. The challenge is to produce products with the lowest MAL-code number possible. "*It is a paradox that many of our products are now so eco-friendly that we need to add preservatives, as otherwise bacteria will become a problem*."

Different motivations are behind different substitution projects. "*It can be because new information is available or new laws have been introduced. But it can also be because we want to improve the product or better our position on the market*." When Dana Lim begins a substitution process – for one reason or another – the first thing they do is to go through all raw materials used - and to find out if a new law is on its way. This way they avoid having to substitute all the time.

The decision to substitute various substances found in joint fillers was made by the management team and the technical department. "*When law changes are the reason behind the substitution, the discussions have been rather brief. In cases like that there really isn't anything to discuss. But when other factors set off the idea of substitutions, the decision is based on agreement between the various departments at Dana Lim*."

Dana Lim uses the substitution principle all the time. "*I don't think any of our products will stay on the market for more than two years – after that, we will need to substitute again*."

The Substitution and Economic Rewards

Whether the substitution resulted in any economic rewards, is a somewhat complex question. Even when products become more expensive after a substitution, it is possible to increase the sale if the improved product is what the consumers want. "*It is difficult to determine whether the increased sale is down to the substitution or something else. On the other hand, if we hadn't completed the substitution, we would not have been able to sell the product at all.*" The rest of the industry also has to substitute continuously. "*Each time the competition presents a product with lower MAL-code numbers, we need to follow suit – if they can, so can we. This way our products are constantly improved. It is very healthy. If we were the only producer of these types of products, there would be no need for us to have a department for development, as we would be able to sell the already existing products. We constantly need to keep up and try to come up with the best possible products. This forces us to stay focused. That is very healthy, I think.*" Dana Lim also refers to the environment in their marketing materials.

It is not possible to produce phthalates free products without increasing the prices. To start with, Dana Lim confronted their costumers with a choice between products with or without phthalates. Many costumers showed an interest in the phthalates free products, but when they were told the price, this interest disappeared. Only very few costumers are willing to pay extra for environmentally friendly products. At the time, the substitution would make no difference to the labelling. But today this has changed. Today, this depends on which phthalates are used. This means that a product without phthalates and a product containing phthalates which do not require labelling, may have the exact same labelling. It is still possible to buy joint fillers with phthalates. But they do not contain any phthalates found on the Danish List of Unwanted Substances.

Challenges and Experiences

The substitution processes have been challenging, but reactions among the employees have been various. Some think the processes are important, and some think the results reached by the development people are absolutely fantastic. "*I think it has been an exiting process. But I also think it takes a lot of knowledge about this area to really comprehend why a certain product is better than other products. There is one thing, though, which is difficult for me to understand. We choose our substances on the basis of the chemicals legislation of today. But as this changes all the time, we sometimes have to substitute. This means that substances which have been part of our production for the past 10 years and always thought harmless, may suddenly be considered dangerous a week from now. Then I have to explain the production workers that the substances they have been working with for the past 10 have been dangerous. They do not feel safe, when they are constantly presented with new projects. People working in the department for development or is a member of the management team do accept that things change and we have to keep up. Similarly, the production workers understand to some extent why it is necessary to substitute. But they might claim that we have used this substance for many years, so why?*"

Finding the right alternative has been a challenge. When one substance is replaced by another, there is always a chance that the effects of the new substance is not as well documented as the effects of the substance that is phased out. Therefore, we might replace one harmful substance with one that is even more harmful. "*This is what REACH may help prevent. We need a clear and reliable legislation, which paint the real and full picture of which substances are harmless and which are not. We need to be able to justify the increased prices to retailers and other costumers. We cannot sell a product that costs 25% more, if the labelling is the same. Therefore we need a more differentiated labelling.*"

"*We are glad that the new stricter regulations are not restricted to Denmark. As otherwise it would be impossible for us to make our international raw materials suppliers react on them. We are glad that more and more regulations are coming from the EU. Because this means that the alternative raw materials are available across Europe.*"

Facts on polyurethane

Polyurethane:
Polyurethanes are polymers formed by diisocyanates and polyalohols – that is alcohols containing more than one OH-group. Both components vary to the extreme and many different compounds with many different characteristics.
Polyurethanes are used in foam, lacquers, joint fillers and insulating materials.

An example of a simple diisocyanate:

$OCN - (CH_2)_6 - NCO$

An example of a simple polyalkohol:

$HO - (CH_2)_4 - OH$

Polyurethane with "n" isocyanate elements, formed by the compounds mentioned above, has the following formula:

$H - (O - (CH_2)_4 - O - CO - NH - (CH_2)_6 - NH - CO -)_n - O - (CH_2)_4 - OH$

The reactive isocyanates give rise to health problems. Therefore, the production of polyurethane causes problems in the working environment. If inhaled, the substance may create coughing, chest paints and other respiratory problems. It may cause irritation to the eyes, nose and throat. If absorbed through skin, the substance may cause problems such as dryness, rash and blisters. Allergies such as respiratory allergies and skin allergies may occur if you are exposed to diisocyanates. Allergies such as these will last for the whole life.

Polyurethane is particularly dangerous during the manufacturing process. But isocyanate is released also when the product is heated (e.g. during welding).

Special precautions must be taken when working with polyurethane.

Facts on oxime

The name oxime refers to a group of chemical compounds formed by aldehydes and ketones in reaction with hydroxylamines.

Butanonoxime is one example:

$$\begin{array}{l} CH_3 \\ | \\ C = N - OH \\ | \\ CH_2 - CH_3 \end{array}$$

Oximes are contained in different types of joint fillers and it may be released during the hardening process. Oximes may cause allergic reactions and is an eye irritant Moreover it may cause cancer.

5.9 Novadan

NOVADAN

An interview with Lis Rasmussen; head of the department for developments and Lisbeth Kjærsgaard, Chemical Engineer.

Novadan manufactures detergents, cleaning agents and disinfectants for the food industry, milk producers, the auto and transport sector, the chemical industry, laundries, and institutions – both public and private. Novadan employs 170 people in Denmark. Novadan has subsidiary companies in Norway, Poland and Iceland and representations in Sweden and Germany. Export to markets in- and outside Europe amounts to 15% of the total turnover.

Novadan has its own laboratory where employees research and develop new improved products always considering the environment and the working environment. The company is certified according to ISO 14001 (the environment) and 9001 (quality). It is member of the Green Network, which is a regional union of 250 companies and public institutions in Vejle County in Jutland, who are dedicated to sustainable production – environment, working environment and social responsibility. Each year Novadan is presenting green accounts. The green accounts state the company's environmental policies and present action plans working as a guide for future activities. All this is done in order to reduce environmental strains. Novadan's products carry the Swan label. Henkel-Ecolab and Novadan are the two major players in the industry and the Danish market is divided almost equally between them.

Novadan wants to:

- introduce quality, environmental and working environmental responsibility at all levels of their production
- convince all suppliers of raw materials, products and services to supply responsibly regarding quality, the environment and the working environment
- strengthen the environment by committing to the principle of sustainable development

Novadan was offered a part in a substitution project. They accepted and decided to substitute surface active substances contained in their products.

Background Information on the Project and the Substitution Process

The Danish Technological Institute contacted Novadan and asked them if they wanted to be part of a project where they together with Henkel-Ecolab would try to develop industrial cleaning agents less hazardous to the environment. Novadan chose to accept the offer because they for some time had experienced pressure form their costumers to deliver environmentally friendly products. Moreover, accepting the offer seemed attractive from an economic point of view, as they only had to pay half the expenses related to the project. "*there was a pressure form our costumers – our costumers had begun to request products more environmentally friendly – then there was the offer to be part of the project – these were the reasons why we embarked on the substitution process*" (Lis Rasmussen).

The aim of the project was to lessen the strains put on the environment by industrial laundries. The specific aim was to substitute the toxic washing agents, which would bio accumulate and were non-degradable, with substances less hazardous to the environment. The main problem is the discharged surfactants, which were difficult to eliminate from the sewage plant. Therefore, a removal of the hazardous substances from the industrial laundries would be a great benefit to the environment. The substitution project ran from February 2001 to August 2002 and the Danish Technological Institute – The Centre for Environment and Waste Technologies and the Centre for Textiles and Clothing – carried out the project together with Novadan and Henkel-Ecolab. They chose to substitute the industrial washing agents because they contain more hazardous substances, as they are used to clean exceptionally soiled textiles (e.g. surgery textiles, kitchen towels from restaurants).

It was Novadan's task to find substitutes for the surface-active substances. They began by asking their suppliers of raw materials if they wanted to assist in finding alternatives to the hazardous substances. The supplier accepted the challenge and suggested a few alternatives. The Danish Technological Institute tested the alternatives in order to make sure they met the environmental requirements. Subsequently, the industrial washing agents' effectivity was tested. A new test method was developed and the newly developed washing agents were then tested according to this new method. The most promising washing agents were chosen among the most effective and most environmentally friendly alternatives. The environmental assessment focused on lowering the score for toxicity and degradability (The GN-Score). This score includes all substances contained in the products, and they are assessed according to quantity, toxicity and degradability. The GN score is lowered when substances less toxic and easier degradable are used. QSAR estimates were used whenever it was not possible to obtain adequate data on the substances[35]. They final test was performed at selected industrial laundries. This was to make certain that the products worked 'in the real world'. None of the suppliers were replaced.

The Substitution: Results and Experiences

The substitution process resulted in two alternative products for each of the two original products. The new products are kinder to the environment and they are just as effective – if not more effective – as the old products. The amount of chemicals used in the new products equals that which was used in the original products. The difference it that the anionic tensides has been replaced by non-ionic tensides. The GB score was low and substances labelled R50 (toxic to organisms living in water) and substances labelled R53 (may have unwanted effects on the water environment) were eliminated. Furthermore, Novadan assessed the overall environmental effects of substances used in their production. And some of these were substituted in some of Novodan's other products.

The new test method developed by the Technological Institute is now applied on

35 (Q)SARs også kaldet "computermodeller" kan bruges til at forudsige kemiske stoffers egenskaber. En SAR eller QSAR model – samlet benævnt (Q)SAR ((Quantitative) Structure Activity Relationships) – er en relation mellem kemiske stoffers strukturegenskaber og en given anden egenskab. Denne anden egenskab kan for eksempel være en fysisk-kemisk egenskab eller en biologisk aktivitet, herunder evnen til at forårsage giftige effekter. Læs mere om QSAR-modeller på Miljøstyrelsens hjemme side www.mst.dk

a daily basis. The test method was made to meet the criteria of the Swan label, and therefore this specific substitution brought about several other substitutions.

Despite the fact that Novadan only paid half the costs of the substitution project, it was still somewhat expensive to run. A person was hired to manage the project from beginning to end. "*It would have cost us more if we had had to do the whole thing on our own. Part of the reason why we chose to go through with it was that we only had to pay half the expenses*" (Lis Rasmussen). To Novadan, the substitution was an investment. The result gained from the project can be applied to other parts of their production. Hence, the new products are priced the same as the old ones.

In general, everyone has been pleased with the project. "*I think it has been an exiting experience involving many challenges. I have gained a lot of new knowledge, which can be directly applied to future activities at Novadan. It was important for us to work with an independent partner – the Technological Institute. They are very experienced and we learned a lot from them. The substitution is useful to us, and the new techniques, programmes and routines can be applied to other areas of our work as well*" (Lisbeth Kjærsgaard). All employees – including those working in the lab – have been exited about the project from its very beginning. Cooperating with the competitor ion has been exiting and a challenge – and a bit out of the ordinary.

The basic principle of the developments and quest for alternatives were communicated to other producers in the industry – without actually revealing any

production secrets. Moreover, the information was passed on to employees working in the lab, the department for developments and to the consultants at the laundry department. This was to give them a sense of being a part of the project.

Novadan's position on the market remains unchanged. The reason being that the market is equally divided between Henkel-Ecolab and Novadan. Nor has the substitution had any effect on their image, as Novadan always inform their costumers about the quality of their products. If the costumers are unhappy with a certain product, Novadan tries to find a solution by discussing the problem with the costumers and with suppliers.

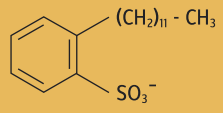
Novadan recommend other companies to substitute. "*If we are to substitute again we would want to include someone independent again*" (Lis Rasmussen).

Facts on surfactants

Surfactants are surface-active agents, and they can be divided into 4 different groups according to their charges in watery solutions. These 4 groups are: anionic (negative charge), non-ionic (neutral), cationic (positive charge) and amphoteric surfactants (positive or negative charge according to pH value). The different groups of surfactants have different properties considering aerobic and anaerobic degradability (oxygen containing or oxygen-free respectively) and toxicity. Often cationic surfactants are slowly degradable, while non-ionic surfactants are easy degradable under aerobic conditions. Moreover, the properties of the substances also differ within the same group, and therefore it is not, as such, possible to generalise on their properties. Surfactants – or detergents – are always partly lipofile (fat-loving and water repellent) and partly hydrofile (water-loving).

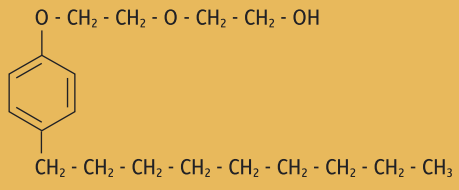
The most commonly used **anionic surfactants** in Denmark are Linear Alkylbenzene Sulphonates, also known as LAS. Less common are alkyl sulphates that are more toxic than LAS. Normally, both LAS and alkyl sulphates are easily degradable under aerobic conditions, but they are not 100% degradable, and therefore small amounts of anionic surfactants may be released from sewage treatment plants into the environment via cleansed waste water. LAS is used as surfactant in detergents and cleaning products. These substances are toxic to organisms living in water. Surfactants in detergents are released when the washing machine has finished washing. Surfactants help to remove fat and protein-containing stains from the laundry. Most surfactants will harm the environment. The ability of the surfactants to dissolve fat and proteins is the main reason for their toxic effects on organisms living in water – including bacteria, algae, crustaceans and fish. Furthermore, they react heavily with organic particles and therefore accumulate in wastewater sludge and sediment. The degree of the damage done to the environment depends on how fast they work and on whether the substance is degraded fully.

One example of a structure of anionic surfactants is as follows:



Non-ionic surfactants consist mainly of the group of substances called alkylphenol ethoxylates (APEO). They improve the miscibility of different substances with water and improve dispersing (fine distribution of pigments, for instance). The alkylphenol part of the APEO often consists of 8 -16 carbon atoms and the degree of ethoxylation (EO) varies from 1 to 30, but normally stays within the spectrum 12 -13 EO. In paints, APEO works both as an independent raw material (e.g. as a dispersing agent) and as part of other raw materials (e.g. in binders or in pigment dispersers). APEO consists of a lipofile alkylphenol part and a hydrofile chain of ethoxylates. Partly due to their low acute toxicity, alkylphenol ethoxylates – especially nonyl and octyl versions – have a range of properties that makes them suitable as surfactants in a long list of products.

An example of a structure for nonylphenol etoxylate:



APEO can be found in detergents, cleaning products, paints & lacquers, cosmetics and as auxiliary components in pesticides. When APEO is biodegraded, alkylphenols – especially nonylphenols – may be created. These are toxic to organisms living in water. The degradation products of APEO are at least five times as toxic to aquatic organisms than is APEO. Eventually, the degradation products may be completely degraded, but this only happens very slowly and only when placed in oxygen containing

continues on page 70

(aerobic) surroundings. They may have endocrine disrupting impacts on living organisms. Even though the use of APEO is declining, APEO and its degradation products occur often and in somewhat high concentration in sludge from wastewater treatment plants, while low concentrations of these substances may occur also in the cleansed wastewater. APEO has been found in soil and aquatic environments in concentrations, which might lead to unwanted effects such as absorption of these substances into eatable plants, as well as bio-accumulation and toxic impact on living organisms.

Because of the toxicity of the degrading product, APEOs have been eliminated gradually in cleaning products. In 1987, the Association of Danish Cosmetics, Toiletries, Soap and Detergent Industry (SPT) made a voluntary agreement with The Danish Environmental Protection Agency (DEPA) to begin a phase-out of APEO. The agreement included only nonylphenol ethoxylates (NPEO). According to information now received from the industry also octylphenol ethoxylates have been eliminated. APEO can be found on DEPA's List of Unwanted Substances. Nonylphenol and nonylphenol ethoxylates are undergoing risk assessments within the EU, and a directive on restrictions on the use of nonylphenol and nonylphenol ethoxylates has now been adopted. Nonylphenol is classified as harmful (to human health) when inhaled, as corrosive and harmful to aquatic organisms, and the substance may have long-term hazardous effects in the aquatic environment. Octylphenols and octylphenol ethoxylates are undergoing risk assessments in the EU. A voluntary agreement states that APEO should not be used in new products, but the substances are not banned in 'old' products in the EU. In Denmark NPEO should not be used at all according to the agreement. APEOs do not require labelling.

Cationic surfactants used today are often quaternary ester compounds. The toxicity of these towards aquatic organisms is quite similar to that of other synthetic surfactants. They are degradable under aerobic conditions.

5.10 Dyrup

An interview with Søren Poulsen; responsible for professional and 'Do It Yourself' (DIY) product developments and Pernille Hjaltelin; responsible for environmental issues

Dyrup is one of Europe's leading producers of wood protection and paint products. Their brands include: BONDEX, DYRUP, GORI and XYLOPHENE. Products are marketed via subsidiary companies in Denmark, France, Germany, Portugal, Spain, Belgium, Austria, Poland, Norway and Sweden. 'DIY' products are primarily sold to DIY store chains. And products aimed at professionals are sold to independent wholesalers and to paint centres in Denmark and Portugal. In Denmark, Dyrup employs 400 people, and the total number of employees worldwide is 1200.

Dyrup has a department for environmental issues covering both product and working environment. The Dyrup Group wants to be known as a company with a clear and sound environmental profile operating at all levels of their business. Dyrup has incorporated their environmental policies into the entire Dyrup Group, and they have introduced a management system covering health, safety and environmental issues. They try to minimise negative effects on the environment and to meet costumer and employee demands in a responsible and sustainable manner. This is done by preventing pollution and other negative effects on the environment and by optimising resource spending, which is done through recycling and reducing resource spending in general, and by improving the production run in such a manner that fewer emissions and less waste are generated. "*We will meet costumer demands where health risks have been well documented. We believe that it would be irresponsible to meet all costumer demands. That would only create an unnecessary fear of environmental effects, which don't even exist. Costumers would become insecure for no reason*" (Søren Poulsen). Furthermore, Dyrup makes an effort to develop, produce and market products, which have no damaging impacts on either humans or the environment insofar as this is technologically and economically feasible. This is done through the composition of the product and through the guide to its use. Green accounting is performed annually and a beneficial dialogue with the local authorities has been established.

Dyrup sells eco-labelled products in Germany and Portugal only. The company has chosen not to sell any eco-labelled products in Denmark. The reason for this decision is that in some areas Dyrup own requirements to their products are stricter than those of the eco-labels and in other areas the requirements of the labels are stricter than Dyrup's own. Dyrup use their own labelling system to show whether the products contain solvents, as this is an issue that seems to concern many costumers. "*The Flower is not helpful to us. It doesn't paint the whole picture. Therefore, we think it would be a waste of our money. If you don't get value for money then it is not a good idea to make the investment. It makes no sense that we have to pay for the label. It ought to be the other way around – that companies had to pay if they did not obtain the eco-label*" (Pernille Hjaltelin).

Dyrup also consult the Danish EPA List of Unwanted Substances. But many of the substances on this have already been regulated and therefore they seldom come across substances that can be found on the list. "*Of course, when we need to use a new substance, we would never choose one that is on the List of Unwanted Substances. The list is a political signal but it does not cover all problems. In other words, a company may use substances which cannot be found on this list but which may still be hazardous to the environment*" (Søren Poulsen).

Why Dyrup Chose to Substitute APEO

An increasing number of injuries in the male reproductive system and a rising incidence of breast cancer among women were observed in the early 1990s. Around the same time, we gained more knowledge about the occurrence of chemical substances and their endocrine disrupting effects. It was discovered that the degradation products from Alkyl Phenol Ethoxylates (APEO) have similarities to that of estrogens. Several studies showed that the product has hazardous effects on the environment and that it is not biodegradable. Investigations were published showing hermaphroditic animals and several investigations had indicated that endocrine disrupting substances such as APEO could

be the cause of these abnormalities. Therefore a dialogue between Dyrup and the local authorities was established. Dyrup was informed about the hazardous effects of APEO, and they agreed to see what could be done about the APEO emission. "*Some studies have shown that APEO is endocrine disrupting, while others examinations have shown the opposite. One of the main reasons why we chose to eliminate APEO was that the substance was suspected to be endocrine disrupting. We need to stick to what we have been shown; we are not experts and therefore it is difficult for us to judge what is right and what is wrong. But we try to stay updated on the latest research. And if we are told that there is a problem with a certain substance, we make up our mind on whether we want to act on it or not. We try not to get involved in the discussion about whether or not APEO is endocrine disrupting. But if something points in that direction, we do want to do something about it*" (Pernille Hjaltelin).

Dyrup have entered into a voluntary agreement to substitute APEO with less hazardous substances in water-based paint products and wood protection products. The agreement was made in connection with Dyrup's environmental approval in Søborg, 1999. APEO works as an emulsifier in paints, wood protection and paint pastes. It guarantees an optimal intermixability of pigments in water solvents. The substitution is an improvement, as the new types of emulsifiers are more degradable; they lead to more water resistant paint and wood protection films, stabilise colour pigments and fillers and they improve mixability of paint pastes without the use of organic solvents (VOC) in all types of paint. There is an extended amount of data available on APEOs and on their effects on the environment, whereas only little is known about the alternatives. Besides, APEO are somewhat universal in their application to paint products. The alternatives have more specific functions. Finally, the substitution project took several years, but costumers did not register nor credit the changes.

APEO is not discharged from the factory. This is due to a settling system which collects the waste water. The main problem with discharged APEO is costumers cleaning their brushes after use, leaving the APEO contained water running down the sewer system. Therefore, Dyrup decided to begin producing paint products without APEO.

Time and Money

The substitutions of APEO with other emulsifiers include many technical reflections:

1. In order to secure a wide colour spectrum and a wide range of products (paint products, wood protection – water based and solvent based) it is essential to operate with universal paint pastes that can be put to use in all combinations and in all product types.
2. If a wrong type of emulsifier is used, this may migrate to the surface of the wood protection film; and together with moist originating from the external environment (damp from indoor use or rain from outdoor use) the emulsifier may create an imperfect finish and hence weaken the protective effect of the product.

3. Emulsifiers affect the absorption of water in the wood protection and hence also in the wood. Exposure to water may shorten the life of the wood.

Dyrup had to find a new supplier in order to go through with the substitution of APEO. It turned out that this new supplier specialises in the exact substance the company wanted to use as a substitute.

Dyrup was one of the first companies to substitute APEO. They began the process in 1993 and in 2000 90% of the total amount of APEO was substitutes; in 2003 most of the remaining bit was substituted as well. Substituting the pastes was the most time consuming part of the entire process. When substituting pastes and paints, it is necessary to study the individual recipes beforehand. Dyrup has spent nearly 20 man- years on the pastes alone; and almost 3 man-years on the paints. "*The substitutions are very demanding. And if we ended up without any positive results, we would have wasted a lot of money which then would have been better spent developing our products*" (Søren Poulsen). Therefore, it is a good idea to combine substitution with product development. Substituting APEO in paints has had no positive impacts on Dyrup's economy; but the substitution in the pastes may result in a modest repayment. But all in all, the substitution has cost more money than they have been able to regain. Nor has the substitution entailed other positive side effects. "*The only thing I can say is that it has strengthened our image as a company that cares about human health and the environment*" (Pernille Hjaltelin).

"*In general, it costs money to substitute. I don't think that can be avoided. Of course, we want to substitute, but we also need to make sure that everything is balanced. Sometimes it can be so expensive that the company ends up on the edge of bankruptcy. This would not be reasonable. On the other hand, we want to substitute where we use substances that have hazardous effects on the environment or are hazardous in other ways. But we need to balance environmental protection against economical interests. This is what is important*" (Søren Poulsen).

Dyrup is aware that – in theory – performing the substitution before the law requires them to might involve competitive advantages. Technically, it is a demanding task to be the first company to carry out the substitution.

Developments and Professional Challenges

The substitution of APEO in paints did not involved improved products; at least not improvements visible to the costumers. The products remained technically the same. The company's environmental profile was improved by the substitution. But this is not always obvious to the costumers. In this case, for instance, there have been no changes to the classifications of the products. "*There is not necessarily any product improvements involved when a company chooses to substitute. But surely it is always more fun if it is possible to improve the products by performing the substitution*" (Søren Poulsen). The paint pastes were actually improved when the solvents were eliminated and the pastes were studied from a to z. "*To a developer, it is a bit more fun to improve the product and not only replace one component with another. This would not be enough to make me*

cheer. A substitution, which does not improve the product, will cost the company money. But a substitution, which improves the product, will help increase profits" (Søren Poulsen).

Finding a suitable alternative has been a personal challenge, and it has helped improve the products technically. "*Development is great fun. But it is no big challenge to just substitute one substance with another. It is elementary and it can be hard to motivate the employees. That is the least exiting part. But if it is possible to combine the bare necessities with something that would improve the product, then the challenge will appear and the whole thing will become much more fun. You are forced to substitute because of circumstances outside the company. It does not always work simply to replace one substance with another. Sometimes the new substance does not fit the other substances, in which case we will have to make huge changes to the recipe. Then the challenge is to understand the process*" (Søren Poulsen).

Image

Dyrup has not made their costumers aware of the elimination of APEOs. This is due to the fact that they did not know the products ever contained the APEOs and that "*according to our policies we do not tell what isn't contained in the products, we only tell what they do contain – that is the kind of information the customers can really use. And we are not allowed to advertise much about the environment – you can so very easily break the EPA's rules*" (Søren Poulsen).

Before the end of the year 2000 the amount of APEO-containing water-based paint products and wood protection had decreased by 70-80%. The substitution made no difference to the factory workers as APEO is not hazardous to the working environment and no changes were made to the production procedures

following the substitution. "*Even though APEO causes no harm to the working environment, it is best to avoid using these substances. Therefore the factory workers experienced no changes, but the working environment was improved nonetheless*" (Søren Poulsen). The costumers were not able to tell any difference in the products after the substitution. The substitution was not a costumer demand, as they were not aware of the existence of APEO in the products. The reason for this is that it is not required that APEO be declared (see facts box). "*I have never experienced costumers contacting us with a wish to have the APEOs removed. Main concerns of costumers are substances that may be a cause of allergies or whether or not it is safe to work with our products if you are pregnant*" (Pernille Hjaltelin).

"*At the moment we don't know much about endocrine disrupting substances. It is still discussed in the EU which tests methods should be used on these substances. And it might be that other substances are just as hazardous as the APEOs. Therefore, it is a good idea to think the whole issue over, before you go out and market your products as free from APEOs*" (Pernille Hjaltelin). The substitution process is a result of team efforts led by the department for developments and the department of environmental issues. When do you make the decision to eliminate certain substances? How much documentation is needed? And when is it necessary to substitute? And when can a substance be said to have hazardous effects on the consumers? The department for developments and the department for environmental issues at Dyrup discussed these issues.

Dyrup wants to actively participate in the protection of the environment and make sure all their products are free from illegal and hazardous substances. And they want to substitute, where the hazardous effects on the environment are well documented.

"*We need to handle these substances properly. We want to do something – it is not just empty phrases*" (Søren Poulsen).

"*I don't know if you could say we are glad we performed the substitution. This is more a question of ethics. We feel it was the right thing to do to get rid of substances, which might be problematic. It is rather a case of us feeling good about having done something good for the environment. But we would not make a big deal out of it by trying to turn it into a selling point. We are just doing the best we can*" (Søren Poulsen).

5.11 Kymi Rens

An interview with Michael Porsmose; Director and responsible for environmental issues.

Kymi Rens (Kymi Cleaning) is a small family owned company with 15 employees. The company was founded in 1939 and since then they have thrived towards keeping their position as a company that relates environmental issues to issues of capacity, quality and technology. They have, several times, been the first company to introduce the latest environmentally friendly technology into the dry cleaning business. Kymi Rens liaise with a number of other companies in order to combine high quality dry cleaning and protecting the environment at the same time. These other companies are: Electrolux Laundry Systems, Chemische Fabrik Kreussler & Co GmbH and AGA/Linde Gas. Originally, Kymi Rens an industrial laundry delivering work uniforms to, for instance, Aalborg Portland and Colorline. However, an increasing part of the production has turned to retail.

Substituting to Environmentally Friendly Cleaning Methods

This is not the first time Kymi Rens has carried out a substitution project. In the beginning of the 1990s, when it was recognised that chlorocarbon was destroying the ozone layer, Kymi Rens tried to find an alternative. Chlorocarbon was banned in the dry cleaning industry in 1995. And instead, Kymi Rens substituted to perchloroethylene, which, at that time, was considered less damaging to the environment. During the following years, they bought so-called hydrocarbon machines, which can remove other types of stains. But there are many disadvantages to hydrocarbon. In this case, hydrocarbon is a kind of white spirit mixture, from which the toxic aromates have been eliminated, but the mixture is still flammable. Moreover, hydrocarbon's specific gravity is close to that of water. It is therefore difficult to separate the cleaning fluid from water, resulting in bacteria growth and bad smell inside the machine.

A few years after perchloroethylene had been introduced, it was discovered that the substance has negative effects. "*We began to look for a more permanent solution. We decided that, instead of throwing good money after bad, it would be better if we could find a product without any damaging effects at all.*" In 1992, Kymi Rens began working together with Electrolux. After a while, Kymi Rens was – as one of the first worldwide – able to introduce AquaClean. AquaClean is a computer controlled washing process that in the cleaning process only uses water. Kymi Rens are slowly replacing all their machines with some using the AquaClean technology. But AquaClean is not capable of doing the whole job, and therefore it was necessary to invest in a CO_2-cleaning machine as well. This machine was then introduced in the year 2000, and, just like the AquaClean machine, it was supplied by Electrolux. Kymi Rens had to go through a development process when the AquaClean machine was introduced. Therefore, when Electrolux began to plan the production of CO_2-cleaning, Kymi Rens volunteered to run tests on the two prototypes. This new method uses liquid CO_2 under high pressure. 3 years back, Kymi Rens had bought CO_2-cleaning machines, and they had previously been part of an EU project during which a CO_2-cleaning method was assessed in order to find out if an alternative to perchloroethylene existed.

Recently, Kymi Rens has introduced GreenEarth, which is a cleaning method based on silicone. It is an American concept, developed by GreenEarth LLC, GE and Proctor & Gamble. This method replaced the one based on perchloroethylene. Now Kymi Rens have three methods based on CO_2, AquaClean and silicone respectively. This means they are now capable of performing a greater variety of tasks. A single method cannot take care of all types of cleaning jobs. From an environmental perspective, having three different methods is an advantage, as for example it would not be possible to remove oil and grease stains using the AquaClean method without having to add several chemicals and increase the energy expenditure. But these stains would fairly easy be removed by means of the CO_2 method.

For a long period of time, the dry cleaning industry received a lot of negative press due to the use of perchloroethylene. Kymi Rens decided to react by trying to turn this negative press into something positive instead. AquaClean has slowly become popular in the dry cleaning business. Whereas CO_2 and silicone based methods are, in Denmark, only used by Kymi Rens. "*It is a very conservative business, to put it mildly*." According to Kymi Rens, the industry has spent too much energy trying to hold on to the perchloroethylene. "*This seems preposterous to us. It should not matter which method is used as long as it works and is not damaging to the environment*."

The Substitution: How Kymi Rens got Started

The substitution became a reality when the Danish legislation – in the form of an executive order – aimed at the dry cleaning industry was issued. The rules concerning environmental protection were tightened. The order was issued in 2003, but Kymi Rens were eager to begin the substitution before the new rules came into effect. This way they had more time to come up with a solution. The environment and the working environment have benefited from the substitution. There was no pressure from the costumers. One thing Kymi Rens has learned from the substitution is that: "*you tend to think that demands are greater than they actually are*." Kymi Rens' costumers never really noticed that their methods had become more environmentally friendly. Only once a costumer has asked about which substances were used, as he had certain allergies. "*Maybe we have won over a few extra costumers, but not many. Costumers expect us to care about environmental subjects. They don't feel they ought to pay extra for that*." Kymi Rens market their services as environmentally friendly, but are far from certain that they will gain more costumers on that account. Being in advance of the legislation is considered an investment. "*If we constantly are trying to keep up with the legislation, I am afraid we would not survive as a business for long*."

It has been necessary to find a new supplier of detergent. The previous supplier was not capable of delivering the correct soap, equipment and proofing suitable for the new machines and cleaning method. They chose a German supplier - now Kymi Rens' only supplier - instead.

Kymi Rens has been working closely together with Electrolux. Kymi Rens ran the tests, and Electrolux's many experts took care of the development of the new machine. "*We were able to contribute on a practical level. Developing a new machine and integrating it into the laundries are two different things*." The cooperation has been a success at all levels. "*It is important to be able to trust each other when working this closely together. A lot of money is at stake*." Kymi Rens came into contact with Electrolux via Michael Porsmose, who is a previous Electrolux employee. It would not have been possible to go through with the substitution without Electrolux.

Experiences

"*In our experience, new environmental regulations often result in new business opportunities*." Kymi Rens has gone from being a dry cleaning business to being a dry cleaning and a laundry business. They have more business now because the laundry business is not depending on any specific time of year. Besides the energy expenditure has been lowered. "*The substitution has been rewarding seen from a financial point of view as well as an environmental point of view*." Kymi

Rens try to stay on the leading edge of the development. It is easier to perform change if done at their own call. But, also, it is exiting being in front.

The employees had no say in the decision-making. But Kymi Rens listened to their opinions and they were taken seriously. They were not a huge part of the process, as the substitution has changed very little in the production process. Therefore none of them had much to add. There have been a few changes affecting the employees, most of them in positive ways. The working environment was improved when organic solvents were replaced by CO_2 and water.

Kymi Rens have seen a few negative side effects as well. Working together with the authorities has been a challenge. They were the first company to use CO_2-cleaning, and therefore they needed to have the method approved by the Working Environment Authority. "*I have never experienced anything like that.*" After 3 months without any response, Electrolux had to step in and demand an answer. They threatened to withdraw the machine if they did not get the approval right away. Kymi Rens then got the approval and they were able to install the machine. Similarly, having the silicon based method approved of was difficult. "*I could wish for the authorities to be a little more flexible in cases such as these.*"

It has been an investment and it has been time consuming – this goes especially for the CO_2-cleaning. For 2-3 years many resources – time as well as money – were spent on the project. But now they are starting to regain some of that money. It is always more expensive to be the first company to introduce a new method. For instance, it would have been so much easier to have the method approved by the authorities, if someone else had already gone through that process. "*Luckily, it is not the expenses but the challenges that keeps us going.*" Furthermore, our network of suppliers has expanded considerably. "*This has contributed to the company image.*" Companies, who wanted to learn from their experiences, have contacted Kymi Rens. AquaClean is now a success in the business. "*We want to recommend others to do the same.*"

"*My motivation was important. I was exited about coming into work every day. There is no doubt that the substitution has been rewarding in every way. It has been hard work and it has been costly, but looking back, it has definitely been worth it.*"

Facts on Chlorocarbon and Perchlorine

Chlorocarbons are hydrocarbons with a maximum of one chlorine-atom attached to each carbon atom, whereas all hydrocarbons are replaced by chlorine in perchlorine compounds. 'Perchlorine' is commenly used as the name for perchloroethylene (tetrachloroethylene). Both chlorocarbons and perchlorines are mainly used in liquid forms and at room temperature.

$CH_3CH_2CH_2Cl$ 1-chloropropane (a chlorocarbon)

$Cl_2C = CCl_2$ Tetrachloroethylene (perchloroethylene)

Both chlorocarbon and perchlorine are – or has previously been – used in the dry cleaning industry.

Chlorocarbons are dangerous when inhaled or swallowed. They may irritate skin, eyes and the respiratory system. In 1995 a law was introduced against the use of chlorocarbons in the dry cleaning industry.

Perchlorine is still commonly used in dry cleaning. It is suspected to cause cancer (carcinogenic class 3) and it is damaging to water environments (R-51/53). Denmark allows a maximum of 0.1 mg/m_3 perchlorine in the air, which is considerably higher than the 0.006 mg/m3 recommended by the health authorities.

Dry cleaners are typically found in city areas and they are often located beneath flats. And perchlorine contained vapour may penetrate into the flats. For these reasons threshold limit values have been lowered and, consequently, many dry cleaners have closed down.

5.12 Kompan

An interview with Hagen Nissen; Section Manager

Kompan was founded in 1970 and has produced playground equipment ever since. The Kompan head office is situated in Ringe on the island of Funen. They own production companies in the Czech Republic and companies all over the world. The Kompan Group employs approximately 400 – 480 people, and in Denmark the number is 170-200 according to season. Kompan is Europe's largest producer of playground equipment and the second largest worldwide.

Kompan does not have a department solely dedicated to environmental issues. Instead, they have a committee dealing with matters of product quality and the environment. This committee also handles matters of eco-labelling and substitution. Moreover, Kompan has incorporated environmental management – the company is certified according to ISO 14001 – and performs environmental accounting yearly. All Kompan's playground equipment is manufactured using materials and technologies affecting the environment as little as possible. All production materials undergo an assessment before they are used. Kompan register the quantity of raw materials used and all waste removed according to their green accounting.

Substitution of Epoxy Filling

Kompan uses two-component epoxies to repair gaps in plywood sheets. Epoxy filling must be labelled, and no one without special training and equipment are allowed to work with it. Besides, it is hazardous to the environment. Since the material must be labelled, it is never delivered to costumers. In fact, it is not possible to order any labelled materials from Kompan. The company has, for a long time, wanted to get rid of all labelled product – including epoxy filling. It has been their ambition to find an alternative, which would not require labelling, and which would not lower the quality of their products. Hagen Nissen presented the management team with the idea of substituting the epoxy filling and with the plan to begin testing alternatives.

Kompan was introduced to Bøgh Consult Denmark A/S at a meeting. And it became clear that they could help finding a solution. Bøgh Consult provided Kompan with several products to be tested at Kompan's own production facilities. If the products passed the tests, they were send on to Kompan's lacquers supplier and working partner, Teknos. Teknos ran a special test that took 9 weeks to complete. The test simulated 10 years of tear and wear. There is a 10-year guarantee on all Kompan products. The tested products possessed good as well as less good qualities, but in the end they discovered a product, which do not

need labelling, is environmentally friendly and of the same good quality as the old product. The new product is a water-based powder filling. Once an alternative was found, the next step was to present it to the management team who needed to approve of it, before it could finally replace the epoxy. The substitution has solved some working environmental issues, but it has done little for the external environment. The reason for this is that an air exhauster was installed where the epoxy was used. The polluted air was led to an incineration plant. This means that the air, Kompan was sending into the external environment, had already been cleansed and the smoke did not exceed the threshold limit values. "*Whether we replace the epoxy filling or not, has no immediate consequence to the external environment, as we were already cleansing the polluted air.*" When the playground equipment is disposed of there is some light pollution. But the filling is only a very small part of the products. "*Regarding the waste, having the epoxy replaced matters a little, but the amount of epoxy was so small, that it would be ridiculous to try to market the company on this improvement*."

The production workers have been part of the process right from its beginning.

Resources and Experiences

The entire substitution period lasted a little over 1.5 years. And around 50-70 hours were spent on the project during that period. The process has cost only very little. "*Compared to the results we have reached, the costs are insignificant*." The limited expenses are down to Kompan running tests themselves, Teknos running tests on their behalf and Bøgh Consult delivering the products for the testing. Kompan now spend less money on protective clothing, and therefore using the new product is less expensive. There was no need to change the production processes.

All employees were pleased with the substitution project, as they were happy to get rid of the uncomfortable protection clothes. "T*here is no doubt that they were glad to see the epoxy disappear. They were all highly motivated during the entire process*." The substitution project sent a positive message to the people working on the production, and it made them even more aware of Kompan's image in general. The company did experience some difficulties, but they were mainly related to technical issues. One difficulty was to find the right product of the right quality. How much will the filling cave, etc? Furthermore, it was vital that the process was kept within the same timeframe; the same goes for the drying time. Luckily, there was no need to replace any other substances to complete the substitution. The long test period was an obstruction. It took 9 weeks to test each product. "*In our case, it was fairly easy to find a replacement. If you make an effort, you will almost always be able to find a solution to your problem*."

Most of Kompan's costumers have not been aware that the products contained epoxy filling, and therefore the substitution will not create any dramatic changes to the sales figures. Yet, it might have an effect in connection with the costumer's seminars held at Kompan. "*There is no doubt that when costumers are taken through the production areas they will look out for signs of epoxy use. When all these signs are removed, the red signs of warning blinking inside the costumer's*

heads will disappear as well. So in that perspective, the substitution can be a selling point." Environmental issues are included in Kompan's sales material. They have no eco-labelled products, but they are about to introduce FSC wood, which has a sustainable production certification.

"*There is no doubt that Kompan is in favour of protecting the environment, especially since our products are aimed at children. I believe we are known as a company that delivers high quality products and cares for the environment at the same time.*" Kompan has been pleased with the substitution and can recommend others to do whatever they can to remove products that need labelling from their production.

"*To me, finding alternative products, which do not require labelling, has been an exiting process.*"

Facts on Epoxy Filling

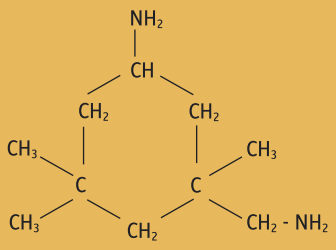
Epoxy filling is a two component epoxy-based material containing a number of substances carrying potential health risks. An epoxy compound can be seen as internal ether formed by two juxtaposed groups of alcohol.

The simplest epoxy compound has the following formula:

Epoxy compounds are extremely reactive. They easily enter a polymerisation process with other compounds – e.g. polyvalent aminos (compounds that have more than one amino group in the same molecule). When the epoxy is mixed with the hardener (the polyamine) the polymerisation will start, and the substance will start to harden.

Epoxy filling contains the following hazardous substances:

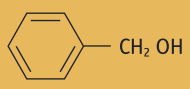
1. 3-aminomethyl-3,5,5-trimethylcyclohexylamine



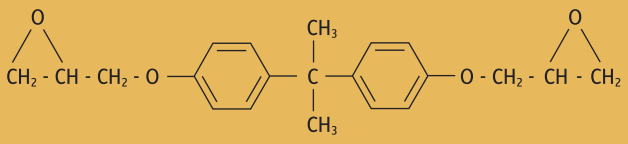
2. Trimethylhexamethylene-diamine

$H_2N - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - NH_2$

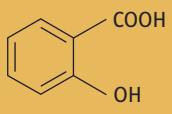
3. Benzylalcohol



4. Bisphenol-A-diglycidylether (epoxy compound)



5. Salicylic acid



The substances listed above are classified as follows: 1 and 2 are both corrosive and may cause allergic reaction when absorbed through the skin. 3 is harmful. 4 is irritant, may cause allergic reactions when absorbed through the skin, dangerous for the environment. 5 is harmful.

Epoxies may be the cause of allergies for people working with the substances. Therefore anyone working with these substances must take special precautions – e.g. special training. The same goes for isocyanates and polyurethanes (see earlier facts box).

LOGSTOR

4.13 Logstor

An interview with Tina Thomsen; Chemical Engineer and Tonny Pedersen; Production Manager

Løgstør Rør was founded in 1960. The company's headquarter is based in Denmark, and it owns production companies in Sweden, Finland and Poland as well as in Denmark. In 2005, the company acquired ALSTROM Power FlowSystem from ALSTROM and today the company is simply called Logstor. In Denmark, Logstor employs 300 people.

Logstor is the leading supplier of pre-insulated pipe systems. The first pre-insulated pipe was produced 40 years ago. In the development of new products, the company always focuses on environmental and energy issues, and throughout the years we have seen several examples of environmentally friendly initiatives at Logstor. For instance, Logstor has acquired recycling facilities that have made it possible for the company to re-use polyurethane and polyethylene found in waste pipes.

There is no department for environmental issues at Logstor. Instead, questions related to the environment are dealt with locally in the various departments. Furthermore, Logstor has a safety organisation which, among other things, deals with environmental issues. Tina Thomsen is responsible for chemicals purchasing at Logstor, and the company has a policy against the use of toxic chemicals.

Facts on Silica Gel

Silica gel (or blue gel) is an adsorptive substance used to de-moisterize the atmosphere surrounding cameras and stereos etc. It is usually placed in small sachets in the packaging for these products. Silica gel is also used to control the moisture contents of grains and seeds during long-term storage. When the silica gel is dry, the colour is blue, but after the gel has picked up moisture from the air, it turns pink or becomes nearly colourless.

Silica gel is a porous, solid material and has the chemical formula of silicon dioxide (SiO_2). It has great water adsorptive power explaining its widespread use as a drying agent. Silicon dioxide is colourless both before and after the absorption of moisture, therefore cobalt chloride is added as a water indicator. Cobalt chloride ($CoCl_2$) is pink, but turns blue when it is lightly heated and thoroughly dried. As Silica gel gradually absorbs water, pink cobalt chloride is reformed.

Silicon dioxide is probably harmless, but cobalt chloride may cause cancer. Because cobalt chloride is not chemically bound to the silica gel, it is easily released and can then be inhaled.

Commercial Silica gel is categorized as very toxic and harmful when inhaled.

Substitution of Desiccants

Desiccants 'drinks up' moisture in the tanks and therewith prevent whatever is in the tanks from being affected by excess moisture. Desiccants are used in the laboratory as well. The substitution project became a reality after employees at the laboratory had read an article about the desiccant: Silica Gel. The article explained that Silica Gel – or Blue Gel – might cause cancer. Moreover, the article mentioned some alternatives to Blue Gel and that it would be easy to embark on a substitution process. Blue Gel is only toxic when it is dried in a drying cabinet, yet still it is on the Danish Environmental Protection Agency's List of Unwanted Substances. Logstor ordered one of the alternative products and started using it in the production instead of Blue Gel, as the new product met their requirements. Blue Gel changes its colour from blue to pink as its water content increases, whereas the new

product changes its colour from light orange to simply clear. When the product has changed its colour, it needs to be re-dried. And when the product has been dried, it can be re-used. This is true for both Blue Gel and the new product.

Experiences

There has been no need to change the production run considerably following the substitution process. But the process has resulted in an improved working environment, insofar as an aspirator was installed and used during the drying of the new product. Logstor Laboratory do not themselves run tests on alternative materials. "*We trust our suppliers completely when it comes to environmental issues. We substitute whenever there is an external demand or if others say we ought to do so.*"(Tonny Pedersen)

The substitution project lasted for 6 months, even though Logstor knew from the beginning which product to use as the substitute. The reason was that there were a large amount of tanks that needed to be emptied and re-filled with the new product. Otherwise, the substitution process has not required much work. The new product is priced the same as Blue Gel. But it has been necessary to find a new supplier.

Logstor's image remains unchanged. "*This is not something our costumers follow up on.*" (Tina Thomsen) Normally, the suppliers inform Logstor about new things happening in the chemical industry. "*Usually, our suppliers inform us when a new rule is on its way, as we don't have our own department for environmental issues. Therefore we are not always aware of it, when new substances are added to the list of unwanted substances. It can sometimes be a problem, as we are sometimes only given a short notice, when we hear about it from our suppliers.*" (Tina Thomsen)

Some of our employees have noticed that it is not as easy to see whether the new product has changed its colour. "*We have experienced technical difficulties.*" (Tina Thomsen). The substitution process has not really been a challenge, but it has been exiting none the less. "*Of course I am glad we decided to substitute. I support the project one hundred percent. I do not want us to work with anything that may cause cancer.*" (Tonny Pedersen) "*It is always exiting to do something good for the employees. This project has been all about that – and of course about finding a substitute which was reasonably priced.*" (Tina Thomsen)

5.14 Frigor A/S

An interview with Karsten Fiil, Maintenance Manager.

Anders Brøndum Holding A/S is a holding company with 3 independent factories: Caravell, Derby and Frigor. All three of them produce refrigerators and freezers. Caravell sells products produced by Frigor. Frigor is a global producer and supplier of refrigerators and freezers. They produce refrigerators and freezers under their own label – mainly for the home market - but they also produce products carrying other labels: Brandt for the Italian market, UPO for the Finnish market and Difriho for the Spanish market. Frigor, depending on the season, employs between 130 and 170 people.

There is no specific department for environmental issues at Frigor, and the company has no written policies covering environmentally related issues. Instead, they act according to their surroundings. Karsten Fiil is responsible for all environmental issues at Frigor.

The Substitution Process

Frigor has substituted the cooling agents used in the cooling system and the blowing agent used in the insulating foam. They have replaced Freon 134A – a HFC (strong greenhouse gas) – with pentane in the foaming process and with isobutene in the cooling system. Freon 134A is still used in some fridges, as some countries do not want to buy products containing isobutene.

Freon 134A is used as a blowing agent for the insulating foam and as refrigerant in the cooling system. The insulating foam consists of isocyanate and polyole, and Freon 134A is added as a blowing agent. The blowing agent is a gas, which blows up the cells creating foam. This foam is used as insulation. Previously, Freon 12 and Freon 24 – both CFCs – were used in fridges, but they were replaced by Freon 134A after it was discovered that they were causing damage to the ozone layer. Primarily, Frigor chose to substitute Freon 134A because the Danish government has decided that the substance must be phased out in Danish fridges and freezers by the end of 2006. So in order to be prepared for this new legislation, Frigor started looking for alternatives. But it soon became apparent that a suitable substitute was discovered years before. In Germany, the industry began to use pentane around the time Danish industry began to use Freon 134A. Thus the whole process of developing pentane as an alternative to Freon 134A had already been completed. Freon 134A was substituted by isobutene in the cooling system.

Frigor began to substitute Freon 134A with pentane in 1999, and the substitution project ran for 9 months. The production workers were not involved in the project from its beginning, seeing that none of them had the necessary information on Freon 134A or on how to find a suitable substitute. The employees had to be trained as isobutene is inflammable. Some rebuilding of the production facilities was also necessary. "*Of course, both people from the maintenance department and people working on the production needed to get involved at one stage. It was a new process and we were working with brand new equipment,*

so, of course, they needed an introduction to all that. But they did not play any part in the decision making." The so-called boxes in the production had to be converted, as it is not possible to use the same box for both Freon and isobutene. The refrigerators and freezers need a different compressor and it was necessary to find out if energy consumption were at the right level. "*This is important, as the consumers want to know about the energy consumption*."

Frigor has a department for developments, which mainly deals with new developments within the areas of technical issues and design. "*Of course, we make sure that the new developments are not harmful*." Often the suppliers are ahead of Frigor and capable of providing guidance regarding matters of substitution. Frigor then runs tests for them. "*Our suppliers have their own labs, and, in fact, they are ahead of us on these matters. And they are the ones who lead the way*."

Experience, Obstacles and Rewards

Isobutene is inflammable and therefore it has not been possible to sell the new freezers and refrigerators containing isobutene in all countries. The new products are mainly sold in Scandinavia and Germany.

The substitution project has been a costly affair – Frigor has spent 400-500,000 Euros on this project. Some of this money was spent on extra man-hours. It was

necessary to call in extra staff, as there were two substitutions running at the same time. From an economical perspective, the project has not been a success. Pentane and isobutene are costly chemicals compared to Freon, and therefore Frigor does not expect to profit from the project. Every year, they now need to have the fire protecting system certified; this was not necessary before the substitution. Yet, Frigor's products have not become more expensive for consumers. Instead, it has been necessary to make the production more effective or – alternatively – to move it to China. "*Since there is an over-production of both freezers and fridges, we cannot set prices ourselves. They are simply sold at their market price*."

There is an increasing demand for environmentally friendly products, yet consumers still take into account factors such as price and energy consumption. "*We were the first company to produce an environmentally friendly box, where we used Freon 134A. We were the first company in the northern part of Europe to produce such a box, but it had no influence on our sales. We did, however, receive several awards for this product*."

"*Personally, I think the process has been interesting, and I am convinced the employees feel the same way. Trying to understand and use new technologies is always a challenge*."

Facts on Freon (CFC, HCFC and HFC)

Freon is a group of short-chained, halogenated hydrocarbons. They contain the elements carbon, fluorine and/or chlorine. Some also contain bromine. Freon are usually gases.

The most common types of Freon can be divided into 3 different groups: CFC (ChloroFluoroCarbons), HCFC (HydroChloroFluoroCarbons) and HFC (HydroFluoroCarbons)

CFCs are completely halogenated and therefore contain no hydrogen. They are used in can sprays, refrigerators, as degreasers, in dry-cleaning etc. The CFCs are severely stable and are only very slowly degraded in the atmosphere. CFCs contribute to the destruction of the ozone layer, as the chlorine atoms react with the ozone molecules and transform them into oxygen. For this reason, it is no longer legal to use CFCs in, for example, the production of new fridges.

One example of a CFC-gas is: CF_2Cl_2 (Freon 12)

HCFC was introduced when the CFCs became illegal. Since they contain hydrogen, they stay for a shorter period of time in the atmosphere. Still, it turned out they contributed to the destruction of the ozone layer.

One example of a HCFC gas is: $CHClF_2$ (Freon 22)

Originally, **HFC** was also developed as a substitute for CFC in the refrigerator industry. As HFC does not contain chlorine, it has no effect on the ozone layer. However, HFC is, like other halogenated hydrocarbons, a very strong greenhouse gas (a thousand times as strong as CO2), and it is toxic as well. HFC is found on the List of Unwanted Substances from the Danish EPA. Hence, in spite of the fact that HFC has no effect on the ozone layer, it is still not a suitable substitute for CFC.

One example of a HFC gas is: CHF_2CF_3 (Freon 134a)

The Montreal Protocol of Substances that Deplete the Ozone Layer was originally signed in 1987. The treaty covers approximately 40 different HCFCs of which only a small number is in use. The EU has set timeframes for phase-outs of CFCs and HCFSs (see regulation 2037/00). According to this, CFC's should be phased out by 1995 and HCFCs by 2010.

It is still legal to use HFCs in the EU. However, they are, together with other industrial greenhouse gasses, covered by the Koyoto Protocol and must be reduced just like CO2, methane etc. Denmark has introduced a national regulation covering the greenhouse gasses. In 2001 a tax on these gasses was introduced, and in 2006 there will be a complete ban on them. It is so far unclear whether the EU will accept this regulation.

6. Summary

The examples given in this publication show that there is a great potential for substitutions, but also that substitution projects are time consuming and often involve extensive research and development processes. Moreover, the examples show that most companies substitute occasionally and for various reasons. As drivers can be identified a need to meet the demands of customers, or it could be because of new legislation, new knowledge or a wish to market themselves as green companies, eventually also in the form of a fear for negative press coverage. Finally, it could be because one of their suppliers had made them aware of new regulations on chemical substances.

Many companies try to always be one step ahead of the chemicals legislation. The reason being that it is easier to make changes at their own pace instead of being forced by new legislation to make these changes. Another reason is that being in front of the competition may be exciting as well as rewarding. Several companies mention the Danish EPA's List of Unwanted Substances as a valuable source of information on which substances might be banned in the future.

Several companies emphasise the importance of including the employees in the substitution processes. Employees are included because of their practical production experiences, and because it gives them a sense of ownership. However, some companies experienced, at first, certain scepticisms among the employees towards the substitution projects. Some employees felt that it was unnecessary to change what had worked so well for so many years. But after the project had been explained to them and they had been included in the process, many began to understand the positive sides of substitution, but occasionally also expressed concerns over earlier practices. Many companies found that job satisfaction was now greater among the employees and that they were pleased with the projects. In addition, many were glad to be working with environmentally friendly products and processes. Several companies mention a larger network and the experience of professional challenges as two additional positive and exciting effects of the projects.

There are many different examples, and this publication is only meant as an appetizer and as a basis for further discussions. It would, for instance, be interesting to study how the authorities' might promote substitutions among private companies, and how the companies might see substitutions as investments and a new way to market themselves. It would also be interesting to study the companies' environmental initiatives on chemicals – innovation, environmental management, environmental communication etc. – and see how these initiatives can be used to promote substitution within the respective companies.

7. Read more

The Ecocouncil: www.ecocouncil.dk
- REACH – a leap forward for industry, made for the Nordic Council of Ministers, 2004
- Bromerede flammehæmmere (Brominated flame-retardents), 2002 (in Danish)
- Kemikalier, miljø og sundhed (Chemicals, the Environment and Health), 2003 (in Danish)
- Instruments for Sustainable Development – Green Taxation, Green Public Procurement Policy and Eco-labelling, 2002

CatSub, www.catsub.dk

The Danish Environmental Protection Agency: www.mst.dk
- On the law on chemical substances and products

The EU Commission: http://www.eu.int/scadplus/leg/en/lvb/l21282.htm
- White Paper – Strategy for a Future Chemicals Policy
- REACH – Regulation proposal

The Danish Working Environment Authority: www.at.dk
Read about working with chemical substances.

Soap and Cosmetics: www.spt.dk
Find the database on chemicals used in the industry (in Danish), and the international organisation for soap industry: http://www.aise-net.org/.

Paint and Lacquers: www.fdlf.dk
For information on the Danish MAL-code system

European Chemical Industry: www.cefic.org
Swedish chemistry NGO secretariat): Chemsec.org

European NGOs dealing with chemicals: www.eeb.org; www.wwf.org; www.greenpeace.org

Danish NGO newsletter: REACH-info: www.reachinfo.dk (in Danish)

Hazardous Chemicals Can Be Substituted

The best way to solve problems arising from dangerous chemical substances is to replace them with less damaging substances. This procedure is called substitution. Substitution is a way to combine environmental improvements with advanced technologies, by which it is often possible to turn environmental issues into a competitive advantage. In Denmark, substitution procedures have been carried out successfully several times.

When is a substance dangerous to the environment and to human health? Often it is difficult to determine how a certain substance is transported or exactly how damaging the substance is to humans and to the environment. But, if the substance in itself is harmful, we will need good reasons to continue using it.

This publication presents experiences concerning substitutions gathered by selected Danish companies. We portray the various environmental issues the companies have helped solve, the substances involved and their environmental and health impacts will be outlined in facts boxes. The publication also tells the personal stories about the professional challenges and obstacles that the people involved have met during the processes. And it tells about the resources and incitements, which have been the motivating factors. Moreover, issues of image and market position in relation to the substitutions are discussed. Finally, the current Danish and EU legislations on chemicals are presented together with the new proposed reform: REACH, in which substitutions play a part.

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