DANTES

Demonstrate and
Assess New Tools
for Environmental
Sustainability

Methods for environmental assessment

- useful to the DANTES project

Johan Widheden, Akzo Nobel Surface Chemistry AB
2002

AKZO NOBEL ABB CHALMERS STORAENSO

SUMMARY

This report was made within the project DANTES that is supported by the EU Life Environment Programme.

The aim of the original report was to identify relevant stakeholders and their perception of environmental performance and also to make a survey of the state of the art regarding available methods and tools for environmental assessment. In this public report only the survey has been included.

The methods are all related to the environmental issues of products and have been divided into Chemical Risk Assessment, Life Cycle Assessment (LCA) and Life Cycle Cost. Furthermore we focus on methods that are of potential relevance for the participating companies in the DANTES project and that could be useful components in the DANTES strategy.

TABLE OF CONTENT

STATE OF ART IN REGARDS OF METHODS AND TOOLS

1.1 Introduction

The methods and tools considered in this report are all connected to the concept of Integrated Product Policy (IPP), i.e. they all deal with the environmental aspects of a product or activity. There are numerous methods for Chemical Risk Assessment that focus on certain groups of chemicals or certain ecosystems, which are not applicable for a chemicals' producer or a certain product and therefore not included in this report.
In this report we will only present a short description of each method/tool. Furthermore we focus on methods that are of potential relevance for the participating companies in the DANTES project and that could be useful components in the DANTES methodology. We have divided the methods and tools into Chemical Risk Assessment, Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) depending on whether they address ecological risks, environmental impact or environmental costs from product life cycles. The methods listed below are to our experience the ones that are most commonly used and further information about them can easily be found in articles, books and on the internet. This list of methods will be updated as we find other methods.

1.1.1 Some definitions

The concepts of Cleaner Production, Design for Environment (DfE) and Life Cycle Management (LCM) are today extensively used. Cleaner Production is as a concept for the continuous application of integrated preventive environmental strategies to processes, products and management, having the purpose of improving environmental performance and efficiency, ensuring cost savings and reducing risks to humans and the environment. DfE is a term for strategies that strive to implement environmental improvements of a product's design into each stage of its life-cycle. LCM is business management based on environmental life cycle considerations.

1.2 Chemical Risk Assessment

1.2.1 Overview of Risk Assessment

Risk Assessment is a method to predict the risk of a human activity having an adverse effect on human health or the environment. The risk is calculated as the product of the probability of an undesired event to occur and the consequences of that event.
Risk Assessment methods can be divided into Risk Assessment of Accidents and Risk Assessment of Chemicals. Risk Assessment of Accidents is mostly used in order to take the right precautionary measures concerning a certain activity. Chemical Risk Assessment is used in order to find out the risk of a certain chemical having adverse effects on human health or the environment, considering the chemicals' use pattern of today. This is achieved by predicting the exposure of a species or ecosystem to the chemical through different exposure routes and comparing this with

the lowest exposure known to have no adverse effect on the species or ecosystem of study.
Estimating environmental concentrations of chemicals by multimedia models require a lot of data on the chemicals and the environmental conditions and also software programs. There are many databases of information on chemicals and many software programs available for Risk Assessments. Specific tools and data sources will be further investigated as the project progresses.

The methods presented below are all Chemical Risk Assessment methods.

1.2.2 Human Health Risk Assessment

This group of methods addresses the risk of a chemical having an adverse effect on human health. The method considers the production, handling, use and waste disposal of the chemical. There are many methods within this group, which focus on specific groups of chemicals or specific health effects, e.g. Neurotoxicity or Cancer Risk Assessment.
The European Chemical Bureau (ECB) has published guidelines for Risk Assessment of new and existing substances, which include human and environmental risk assessment of chemicals. These can be found at http://ecb.jrc.it. The ECB recommends using a software tool called EUSES (European Union System for the Evaluation of Substances) that can be found at http://ecb.jrc.it/Euses/.
The US EPA publishes information on Human Health Risk Assessment at http://www.epa.gov/oerrpage/superfund/programs/risk/.

1.2.3 Environmental Risk Assessment

An Environmental Risk Assessment focuses on the adverse effects of specific chemicals or groups of chemicals, wherever these effects may occur. An environmental exposure to the chemical is predicted and compared to a predicted no-effect concentration, supplying risk ratios for different media. A multimedia and fate model is used for calculating the environmental exposure and this requires some kind of software. The software tool EUSES mentioned above is also recommended for Environmental Risk Assessment.
Information on Environmental Risk Assessment is published by the European Chemical Bureau (http://ecb.jrc.it) and the OECD (www.oecd.org), among others.

1.2.4 Screening Environmental Risk Assessment

The European Commission has published a white paper called “Strategy for a Chemicals Policy” where a new system of chemicals control is presented. In this system chemicals’ producers are obliged to submit preliminary risk assessments that cover the intended uses of their chemicals. To facilitate these risk assessments the European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC) is developing a simplified procedure that assesses chemicals by using some easily accessible data and without having to use multimedia models.
This procedure is not yet published.

For further information about ECETOC, see www.ecetoc.org.

1.2.5 Ecological Risk Assessment

An Ecological Risk Assessment focuses on a particular area and evaluates the potential adverse effects that human activities have on the plants and animals that make up ecosystems. There are Ecological Risk Assessment methods that focus on specific kinds of areas, such as watersheds. Information on Ecological Risk Assessment can be found at http://www.epa.gov/superfund/programs/risk/ecolgc.htm and http://www.setac.org/eraag/era_index.htm.

1.2.6 Aquatic and Terrestrial Risk Assessment

The general methods for Ecological and Environmental Risk Assessment have been developed specifically for aquatic and terrestrial environments by FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act) and the OECD (Organisation for Economic Co-operation and Development).
The FIFRA Aquatic and Terrestrial Risk Assessment comprises tools and processes for predicting the magnitude and probabilities of adverse effects to non-target aquatic and terrestrial species resulting from the introduction of pesticides into their environment. Information about the FIFRA Risk Assessment methods can be found at http://www.epa.gov/oppefed1/ecorisk/.
The OECD has published guidelines for aquatic and terrestrial risk assessments, which are applicable to chemicals in general and focus on the effects of specific chemicals on the aquatic and terrestrial environment. These can be found at www.oecd.org.

1.2.7 Ecotoxicological Impact Assessment, Omniitox methodology

The OMNIITOX project will facilitate decision making regarding potentially hazardous compounds by improving methods and developing information tools necessary for impact assessment of toxic chemicals within Life Cycle Assessment and (Environmental) Risk Assessment. The project will provide operational models and information tools that will promote the choice of more environmentally benign chemicals.
As of today, there are no results available from the project, but information will be posted at http://www.omniitox.net/.

1.3 Life Cycle Assessment

In this group we have listed the methods that consider the environmental aspects of the life cycle of a product or service.

1.3.1 Full Life Cycle Assessment (LCA)

An LCA is a comprehensive assessment of the potential environmental impact from the entire life cycle of a product, i.e. from its “cradle “to its “grave”. The method for conducting LCAs has been standardized by the International Standardization Organization (ISO) in the ISO 14040-series. LCA can be used to compare alternative products, processes or services and can also be used as a basis to communicate environmental performance e.g. with an Environmental Product Declaration (EPD; see

below). A full LCA is a time consuming activity and thus fairly costly. It is therefore primarily used by larger companies.
Some kind of software is usually required for a full LCA and there are many software programs available for LCA. Most of these software programs can be found at http://www.life-cycle.org/LCA_soft.htm.
Information can be found at:
http://www.ecosite.co.uk
http://www.lcacenter.org/
http://www.life-cycle.org/
http://faculty.washington.edu/cooperjs/Education/LCAcurriculum/lca_curriculum.htm
http://www.setac.org/lca.html
http://www.iso.ch/ (technical committee 207/sub-committee 5 in ISO)

1.3.2 USES-LCA

The USES-LCA model uses the multimedia fate, exposure and effect model USES 2.0 with preset environmental parameters to calculate impact assessment indexes for ecological toxicity.
The report on USES-LCA can be downloaded from http://www.leidenuniv.nl/interfac/cml/ssp/projects/lca2/report.pdf
Information on USES can be found at http://arch.rivm.nl/csr/risk.html.

1.3.3 Screening, Simplified and Streamlined LCA (SLCA)

The concepts of Screening, Simplified and Streamlined LCA are often mixed as they are all dealing with trying to simplify the LCA procedure. Since simplifications are always present in an LCA there is not a well-defined distinction between an SLCA and a full LCA. It is up to the practitioner of the LCA to define whether it is a full LCA or a Screening LCA. In some references Streamlined LCA is identical to Screening LCA, and in one reference Streamlined LCA is one specific methodology for conducting Simplified LCA (Finnveden et.al., 2002), developed by Gaedel (Graedel, 1998). Another method for Simplified LCA, or more correct to apply a life cycle perspective, would be the MET-matrix or the DfE Strategy Wheel (see below). In the final report from the SETAC (Society of Environmental Toxicology and Chemistry) Streamlined LCA Workgroup, they equate Streamlined LCA with Screening LCA and Simplified LCA (Todd and Curran, 1999).
Screening LCA can be used to distinguish the most important environmental effects of a product's life cycle and which parts of the life cycle that give rise to these effects. It can also be used in order to find the most important data gaps. A Simplified or Streamlined LCA (see below) is usually preceded by a Screening LCA, but a Screening LCA can also be used by itself to identify where in a product life cycle specific chemicals are emitted. This information can then be used as a basis for other assessments, such as Environmental Risk Assessment or as a basis for improvements.
Energy flows, mass flows or flows of specific chemicals of interest can be used as indicators for Screening LCAs. Indicators can also be found by

conducting a qualitative LCA, such as the MET-matrix (see below), which is an even further simplified LCA.

There are numerous software tools for SLCA (often called tools for DfE) and we do not present any here, but some of them can be found at http://www.life-cycle.org/LCA_soft.htm.

References:

Fet, A.M., 1995, *Life Cycle Screening - an appropriate methodology for identifying environmental key issues in the Ship Industry*, Report Å 9517, Møre Research, Ålesund, Norway.

References to Streamlined LCA methodology:

Graedel, T. E., 1998, *Streamlined Life-Cycle Assessment*, Prentice Hall.

Finnveden, G., Hochschorner, E., Johansson, J., 2002. *Utvärdering av två förenklade metoder för livscykelanalyser*. ISSN 1650-1942. In Swedish.

Todd, J.A., Curran, M.A., 1999, *Streamlined Life-Cycle Assessment: A Final Report from the SETAC North America Streamlined LCA Workgroup*. SETAC.

1.3.4 Simplified LCA matrices

These matrices are fast, qualitative methods to find the environmental impact from the life cycle of a product. The matrices consider all the life cycle phases and include consumed energy and material and toxic emissions from these phases. Simplified LCA matrices are meant to be used by product designers in co-operation with someone with knowledge of environmental aspects and there is therefore no need for a software tool. Some examples of simplified LCA matrices are the MET matrix, the MECO matrix and the Streamlined LCA according to Graedel (see above).

References:

MET matrix: Norrblom, H.L., Jönbrink, A.K., Dahlström, H., 2000, *Ekodesign – praktisk vägledning*. Institutet för Verkstadsteknisk Forskning, Sweden.

MECO matrix: Pommer K., B. Bech P., Wenzel H.., Caspersen N., Olsen S. I., (2001). Håndbog i miljøvurdering af produkter -en enkel metode. Miljønyt Nr. 58 2001, Miljøstyrelsen, Miljøog Energiministeriet: 187. Denmark. (In Danish)

1.3.5 Environmental Product Declaration (EPD)

An environmental product declaration, EPD, is defined as "quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information". An EPD is a product declaration directed towards professional purchasers. It is based on a third party certified LCA according to the ISO 14040 standards

The overall goals of an EPD is, "through communication of verifiable and accurate information, that is not misleading, on environmental aspects of products and services, to encourage the demand for and supply of those products and services that cause less stress on the environment, thereby stimulating the potential for market-driven continuous environmental improvement".

Information can be found at www.environdec.com.

1.3.6 Environmental Development of Industrial Products (EDIP)

This is a complete method for including environmental aspects in the product development phase but is also often referred as a LCA weighting method. The method is based on LCA and in accordance with international consensus in the leading scientific societies and standardization organizations, including ISO. It was developed in close collaboration between the Danish EPA, the Technical University of Denmark (Institute for Product Development and Department of Technology and Social Sciences), Confederation of Danish Industries and five leading companies: Bang & Olufsen A/S, Danfoss A/S, Gram A/S, Grundfos A/S and KEW A/S. A software tool has been developed for the EDIP methodology and can be found at http://www.mst.dk/activi/08030000.htm.

References:

Wenzel, H., Hauschild, M. and Alting, L., 1997, *Environmental Assessment of Products.*
Volume 1: Methodology, tools and case studies in product development. and
Volume 2: Scientific background. By Hauschild, M. and Wenzel, H. Published by Chapman & Hall.

1.3.7 Miljø-QFD (Environmental Quality Function Deployment, QFD)

QFD, developed within Japanese industry in the 1970s, is one of the most significant methods for introducing customer requirements (often called the voice of the customer, (VOC) into product development. Various methods for increasing the influence of customer demands in LCA have been developed using QFD, for example "Quality and Environment Function Deployment (QEFD)". QEFD is described by Olesen *et.al.* as a method that combines QFD with screening life-cycle assessment, focusing on the design task by early observation and identification of the stakeholders' reactions to the quality and environmental properties of the product for the purpose of improving the product's market position. The stakeholders who have the greatest influence on buying decisions are interviewed with regard to a reference product, and an LCA is performed concurrently. "Green Quality Function Deployment-II (GQFD-II)", and "QFD for Environment (QFDE)", are similar concepts in eco-design, using QFD to enhance customer representation.

This is a Danish model that combines QFD with screening life-cycle assessment systematically considers environmental properties in product development for the purpose of improving the product's market position. There are numerous software tools for QFD, but at present no specific software have been found for Environmental QFD. In the Nordic Project on Environmentally Sound Product Development a method for "Sustainable product design" was developed and tested. This method included LCA, LCC and QFD and should be of big interest in the DANTES project.

References:

Olesen J., (1997), Environmental QFD – The Creation of Project Focus, Proceedings of ICED, International Conferences on Engineering Design, Tampere, Finland. A working report of this method (Arbejdsrapport 4,

1997, *Synliggørelse af produkters miljøegenskaber. In Dansih)* can be downloaded from the Danish Environmental Protection Agency at www.mst.dk.
Zhang Y., Wang H-P, Zhang C., 1998, *Product Concept Evaluation using GQFD-II and AHP*, International Journal of Environmentally Conscious Design & Manufacturing, vol. 7, No. 3.
Masui K., Aizawa S., Sakao T., Inaba A., 2000, *Design for Environment in Early Stage of Product Development Using Quality Function Deployment,* Proceedings of Joint International Congress and Exhibition Electronics Goes green 2000+, vol1.
Information on QFD can be found at http://www.qfdi.org.
Karlson L, Rydberg T, Sjöström K, Larsson P, Videsson A, Hanssen O J (1995), *Environmentally Sound Product Development of Installation Cable,* Nordic Project on Environmentally Sound Product Development, NEP report 05/95, Chalmers Industriteknik, Göteborg, Sweden

1.3.8 Environmental Effect Analysis (EEA; or Environmental Failure Mode and Effect Analysis, E-FMEA))

The purpose of EEA is to identify and assess a product's significant environmental impact early in the product development process, in order to minimize the adverse environmental impact of the product's life cycle as cost-efficiently as possible. EEA is a qualitative method primarily intended for internal use. The applied EEA method varies according to application and demands, but it includes an inventory of environmental impacts from the product life cycle, a valuation of these impacts and a remediation plan to minimize the impacts.

References:

Lindahl M. and Tingström J. 2000. *En liten lärobok om Miljöeffektanalys.* Institutionen för Teknik, Högskolan i Kalmar, Sverige (in Swedish)
Magnusson, T. och B. Franzén (1999). *Miljöeffektanalys - ett hjälpmedel vid miljöanpassad produktutveckling*. Sveriges Verkstadsindustrier, Industrilitteratur AB, Stockholm (in Swedish).

1.3.9 Design for Environment (DfE) Strategy Wheel

The Strategy Wheel is used in the early stages of the product development process and covers design, materials selection, production, distribution, use and end of a product's life. The tool provides a basic framework that you can be used systematically to review the entire life cycle of a product. It may also be used as a basis for brainstorming to highlight activities in a products' life cycle that may have an impact on the environment. The DfE Strategy Wheel should be used in a group discussion and therefore does not require a software tool. Documents describing the method can be downloaded from the National Research Council of Canada (see below)
The method can:

- Stimulate the creative design process.
- Assist in visualizing current environmental performance.
- Highlight opportunities for improvement.

A software tool for the Strategy Wheel can be found at http://www.io.tudelft.nl/research/dfs/ecoquest/Ecoquest.html.
Information about the DfE Strategy Wheel can be found at many departments and institutions working with Design for Environment, e.g. http://www.nrc.ca/dfe/ehome/dfestra/dfestraintro/dfestraintro.html
Another reference: Norrblom, H.L., Jönbrink, A.K., Dahlström, H., 2000, *Ekodesign – praktisk vägledning*. Institutet för Verkstadsteknisk Forskning, Sweden.

1.3.10 Material Intensity Per Unit Service (MIPS)

The MIPS method is a Material Flow Analysis (MFA) used for products. MIPS is similar to LCA but MIPS is a more "crude" method that puts focus only on the material inputs. MIPS is computed in mass of material input per total units of service delivered by the good over its entire life span. The material inputs are categorized into biotic and abiotic material, water, air and soil and the amounts are calculated based on a functional unit for the product or service under consideration. The result can be presented in a so called ecological rucksack, which is a measure of the amount of material affected by the life cycle of a product. The MIPS method
This tool is fairly simple to use and the result is easy to understand.
A lot of information can be found at http://www.wuppertal-institut.de/Projekte/mipsonline/ (in German).

1.4 Life Cycle Cost

1.4.1 Introduction

Life-Cycle Costing (LCC) was originally developed by the U.S. Department of Defense in the 1960s to improve acquisition and procurement of for example weapons systems. In the 1980s LCC became popular as, for example, a tool for Life-Cycle Management (LCM) for products. Then, in the 1990s LCC entered the environmental management domain. Throughout the various applications of LCC two core aspects have remained the same; 1) include total costs and 2) consider the entire life-cycle of a system (product, service, infrastructure, etc.).
Life cycle costs can be described as the internal and external costs that arise during the life cycle of a product, process or activity, i.e. from extraction of raw material, production, investments, usage, maintenance and end-of-life. Internal costs are the costs for the company and external costs are the costs for society.
There are many terms for tools that estimates costs from a life cycle perspective. The costs included in such estimations are not always the same.
Many software programs for LCC can be found at http://www.plant-maintenance.com/maintenance_software_availability.shtml.

1.4.2 Environmental Management Accounting (EMA)

Management accounting can be described as the identification, collection, estimation, analysis, & use of cost & other information for decision-making within an organization.
Environmental Accounting is a broad term that is used in several different contexts, such as management accounting, financial accounting, and national accounting. We will focus on the application of Environmental Accounting for internal organizational decisions, i.e., Environmental Management Accounting. Environmental Management Accounting has a particular focus on materials & energy flow information and environmental cost information.
More information can be found at:
http://www.emawebsite.org/index.htm
http://www.eman-eu.net/
http://www.epa.gov/opptintr/acctg/pubs/busmgt.pdf

1.4.3 Environmental Financial Accounting (EFA)

Financial Accounting can be described as the development & reporting of financial information by an organization to external parties (e.g., bankers, stockholders).
Included in the Environmental Financial Accounting category are valuation approaches and tools that have been specifically developed or adapted for estimating environmental liability costs for consideration in business management decisions such as capital investments, process/input substitutions, product retention and mix, facility siting, and waste management. The emphasis is on techniques for placing a monetary value on potential, preventable environmental liabilities. A number of methods are evaluated in a report from the US EPA and can be found at http://www.epa.gov/opptintr/acctg/pubs/liabilities.pdf.

1.4.4 Systematic approach to environmental priority strategies in product development (EPS)

The EPS system is developed to assist designers and product developers in finding which one of two product concepts that has the least impact on the environment. The EPS system is based on Life Cycle Assessment methodology and evaluates the willingness to pay for a healthy environment within the OECD. There is a potential risk that a human activity, e.g. emissions of chemicals or extraction of resources, will cause an adverse effect on the environment. The EPS system is a method to evaluate the economical consequences of human activities based on peoples' willingness to pay for avoiding the adverse effects that may be caused by human activities. The EPS system takes into consideration the adverse effects on Human health, Ecosystem production capacity, Abiotic stock resources, Biodiversity and Cultural and recreational values.
The EPS system is primarily used as an evaluation tool within LCA.
More information can be found at www.cpm.chalmers.se.

1.5 Combinations of the methods described above and other methods and tools

1.5.1 Cleaner Technologies Substitutes Assessment (CTSA)

CTSA is a methodology for evaluating the comparative risk, performance, cost, and resource conservation of alternatives to chemicals currently used by specific industry sectors. The CTSA methodology was developed by the U.S. Environmental Protection Agency (EPA) Design for the Environment (DfE) Program, the University of Tennessee Center for Clean Products and Clean Technologies, and other partners in voluntary, cooperative, industry-specific pilot projects.
The entire method can be found and downloaded at http://www.epa.gov/opptintr/dfe/pubs/pdf/tools/ctsa/index.html

1.5.2 BASF Eco-efficiency Analysis

BASF has developed a tool of eco-efficiency analysis to address not only strategic issues, but also issues posed by the marketplace, politics and research. It was a goal to develop a tool for decision-making processes which is useful for a lot of applications in chemistry and other industries. The tool considers material consumption, energy consumption and emissions for the life cycle of the product and also the toxic potential (risk phrases) and risk potential of hazards. These parameters are compared with the total costs over the life cycle. The costs are the real costs that occur and the subsequent costs that will occur in the future. The result is a portfolio plot for eco-efficiency with environmental impact on one axis and total costs on the other. More information can be found at http://www.basf.de/en/corporate/sustainability/oekoeffizienz/.

1.5.3 Activity-Based Cost and Environmental Management

This method is also called Activity-Based LCA and has been developed by Jan Emblemsvåg. No further information could be found.
http://www.emblemsvag.com/

Reference:

Emblemsvåg, J., Bras, B., *Activity-Based Cost and Environmental Management: A Different Approach to the ISO 14000 Compliance.* Kluwer Academic Publishers, Boston

1.5.4 Total Cost Assessment Methodology (TCA)

Total Cost Assessment Methodology (TCA) provides a disciplined and standardized approach to identifying all life-cycle costs and benefits associated with decisions related to environmental, safety and health (ESH) issues for industrial products and processes.
More information and software tools can be found at http://www.sylvatica.com/tools.htm and http://www.aiche.org/cwrt/projects/cost.htm.

1.6 Methods to include in the DANTES project

Since we propose to find tools and methods for many different situations, most of the tools listed will be considered for DANTES strategy even if only a few methods will be directly included in the DANTES strategy.

Regarding Chemical Risk Assessment methods we will focus on the Environmental Risk Assessment, but also include Ecological Risk Assessment and Human Risk Assessment.

The life cycle related methods presented above represents different levels of detail and also have different intended users. All of them can therefore be the best tool in a specific given situation and may therefore be important to include in the DANTES strategy.

Regarding the LCC methods we have as yet only covered two large groups of methods for environmental accounting and not been able to assess specific methods for setting a price on the environmental impacts of a product life cycle. The methods will be studied further to find appropriate specific tools and methods to include in the project.

Important methods and tools not found or assessed yet will be included as they are found and assessed.

It is however important to have an open mind about what methods to include in the DANTES strategy since this depends strongly on the user requirements that is not studied in detail yet. The potential methodologies presented in this report will therefore be carefully reviewed and considered after the user requirements have been identified and summarized.