

## Henrik Fred Larsen - DTU Orbit (07/08/2016)

Henrik Fred Larsen

### Organisations

#### Department of Management Engineering

25/06/2012 → 03/09/2013 Former

[hfla@dtu.dk](mailto:hfla@dtu.dk)

VIP

#### Senioringeniør, Institute for Product Development

04/07/2003 → 03/09/2013 Former

[hfl@ipl.dtu.dk](mailto:hfl@ipl.dtu.dk)

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#### Senior Researcher, Department of Management Engineering

04/07/2003 → 03/09/2013 Former

[hfla@dtu.dk](mailto:hfla@dtu.dk)

VIP

#### Quantitative Sustainability Assessment

25/02/2012 → 02/09/2013 Former

VIP

### Publications:

#### Endpoint characterisation modelling for marine eutrophication in LCIA

##### General information

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Cosme, N. M. D. (Intern), Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Pages: 54-55

Publication date: 2013

##### Host publication information

Title of host publication: Abstract book - SETAC Europe 23rd Annual Meeting

Main Research Area: Technical/natural sciences

Conference: SETAC Europe 23rd Annual Meeting, Glasgow, United Kingdom, 12/05/2013 - 12/05/2013

Electronic versions:

[SETAC\\_abstracts\\_meeting\\_13.pdf](#)

##### Relations

Activities:

SETAC Europe 23rd Annual Meeting

Source: dtu

Source-ID: u::9124

Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2013

#### Endpoint characterisation modelling for marine eutrophication in LCIA

##### General information

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Cosme, N. M. D. (Intern), Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Number of pages: 20

Publication date: 2013

##### Publication information

Media of output: PowerPoint

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

Endpoint characterisation

### Relations

Activities:

SETAC Europe 23rd Annual Meeting

Publication: Research › Sound/Visual production (digital) – Annual report year: 2013

### Final evaluation of the newly developed characterisation and normalisation factors in an LCA case study - Paper production and printing

#### General information

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Cosme, N. M. D. (Intern), Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Number of pages: 90

Publication date: 2013

#### Publication information

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

Final\_evaluation\_of\_the\_newly\_developed.pdf

#### Bibliographical note

Deliverable report no. D4.10 (EU project LC-IMPACT (243827 FP7-ENV-2009-1) (Development and application of environmental Life Cycle Impact assessment Methods for imProved sustainability Characterisation of Technologies).

Publication: Research › Report – Annual report year: 2013

### Including Life Cycle Assessment for decision-making in controlling wastewater nutrient removal systems

This paper focuses on the use of Life Cycle Assessment (LCA) to evaluate the performance of seventeen control strategies in wastewater treatment plants (WWTPs). It tackles the importance of using site-specific factors for nutrient enrichment when decision-makers have to select best operating strategies. Therefore, the LCA evaluation is repeated for three different scenarios depending on the limitation of nitrogen (N), phosphorus (P), or both, when evaluating the nutrient enrichment impact in water bodies. The LCA results indicate that for treated effluent discharged into N-deficient aquatic systems (e.g. open coastal areas) the most eco-friendly strategies differ from the ones dealing with discharging into P-deficient (e.g. lakes and rivers) and N&P-deficient systems (e.g. coastal zones). More particularly, the results suggest that strategies that promote increased nutrient removal and/or energy savings present an environmental benefit for N&P and P-deficient systems. This is not the case when addressing N-deficient systems for which the use of chemicals (even for improving N removal efficiencies) is not always beneficial for the environment. A sensitivity analysis on using weighting of the impact categories is conducted to assess how value choices (policy decisions) may affect the management of WWTPs. For the scenarios with only N-limitation, the LCA-based ranking of the control strategies is sensitive to the choice of weighting factors, whereas this is not the case for N&P or P-deficient aquatic systems.

#### General information

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment, Université Laval, Lund University

Authors: Corominas, L. (Ekstern), Larsen, H. F. (Intern), Flores-Alsina, X. (Ekstern), Vanrolleghem, P. A. (Ekstern)

Keywords: (ASM3-BioP, Control, Decision making, LCA, Mathematical modelling, Nutrient removal, Sustainability, Wastewater treatment, Weighting)

Pages: 759-767

Publication date: 2013

Main Research Area: Technical/natural sciences

#### Publication information

Journal: Journal of Environmental Management

Volume: 128

ISSN (Print): 0301-4797

Ratings:

BFI (2015): BFI-level 2

Scopus rating (2015): 1.206 1.65

BFI (2014): BFI-level 2

Scopus rating (2014): 1.251 1.898

BFI (2013): BFI-level 2  
Scopus rating (2013): 1.21 2.013  
ISI indexed (2013): ISI indexed yes  
BFI (2012): BFI-level 2  
Scopus rating (2012): 1.381 2.511  
ISI indexed (2012): ISI indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): 1.221 2.187  
ISI indexed (2011): ISI indexed yes  
BFI (2010): BFI-level 2  
Scopus rating (2010): 1.152 1.682  
BFI (2009): BFI-level 2  
Scopus rating (2009): 0.968 1.689  
BFI (2008): BFI-level 2  
Scopus rating (2008): 0.761 1.316  
Scopus rating (2007): 0.918 1.463  
Scopus rating (2006): 0.828 1.38  
Scopus rating (2005): 0.672 1.092  
Scopus rating (2004): 0.531 1.055  
Scopus rating (2003): 0.628 0.912  
Scopus rating (2002): 0.386 0.805  
Scopus rating (2001): 0.469 0.94  
Scopus rating (2000): 0.409 0.982  
Scopus rating (1999): 0.391 0.618  
Original language: English

DOIs:

10.1016/j.jenvman.2013.06.002

Source: dtu

Source-ID: n::oai:DTIC-ART:elsevier/391329486::31582

Publication: Research - peer-review › Journal article – Annual report year: 2013

### **Modelling micro-pollutant fate in wastewater collection and treatment systems: status and challenges**

This paper provides a comprehensive summary on modelling of micro-pollutants' (MPs) fate and transport in wastewater. It indicates the motivations of MP modelling and summarises and illustrates the current status. Finally, some recommendations are provided to improve and diffuse the use of such models. In brief, we conclude that, in order to predict the contaminant removal in centralised treatment works, considering the dramatic improvement in monitoring and detecting MPs in wastewater, more mechanistic approaches should be used to complement conventional, heuristic and other fate models. This is crucial, as regional risk assessments and model-based evaluations of pollution discharge from urban areas can potentially be used by decision makers to evaluate effluent quality regulation, and assess upgrading requirements, in the future.

### **General information**

State: Published

Organisations: Department of Environmental Engineering, Urban Water Engineering, Department of Management Engineering, Quantitative Sustainability Assessment, Ghent University, CH2M HILL Inc., Hydromantis Environmental Software Solutions, University of Windsor, L'Institut National de la Recherche Agronomique, Université Laval

Authors: Plósz, B. G. (Intern), Benedetti, L. (Ekstern), Daigger, G. T. (Ekstern), Langford, K. H. (Ekstern), Larsen, H. F. (Intern), Monteith, H. (Ekstern), Ort, C. (Ekstern), Seth, R. (Ekstern), Steyer, J. (Ekstern), Vanrolleghem, P. A. (Ekstern)

Keywords: (biotransformation and cometabolism, parent chemical retransformation, risk assessment and regulations, sorption-desorption, trace chemicals)

Number of pages: 15

Pages: 1-15

Publication date: 2013

Main Research Area: Technical/natural sciences

### **Publication information**

Journal: Water Science and Technology

Volume: 67

Issue number: 1

ISSN (Print): 0273-1223

Ratings:

BFI (2015): BFI-level 1

Scopus rating (2015): 0.469 0.552

BFI (2014): BFI-level 1

Scopus rating (2014): 0.6 0.678

BFI (2013): BFI-level 1

Scopus rating (2013): 0.563 0.698

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 1

Scopus rating (2012): 0.589 0.666

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 1

Scopus rating (2011): 0.608 0.648

ISI indexed (2011): ISI indexed yes

BFI (2010): BFI-level 1

Scopus rating (2010): 0.547 0.605

BFI (2009): BFI-level 1

Scopus rating (2009): 0.593 0.646

BFI (2008): BFI-level 2

Scopus rating (2008): 0.585 0.696

Scopus rating (2007): 0.755 0.781

Scopus rating (2006): 0.704 0.793

Scopus rating (2005): 0.774 0.86

Scopus rating (2004): 0.885 0.917

Scopus rating (2003): 0.88 0.898

Scopus rating (2002): 0.903 0.885

Scopus rating (2001): 0.758 0.968

Scopus rating (2000): 0.765 0.895

Scopus rating (1999): 0.882 0.939

Original language: English

Source: dtu

Source-ID: n::oai:DTIC-ART:pubmed/373694164::20947

Publication: Research - peer-review › Journal article – Annual report year: 2013

## **Recommended assessment framework, method and characterisation and normalisation factors for ecosystem impacts of eutrophying emissions: phase 3 (report, model and factors)**

### **General information**

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Azevedo, L. (Ekstern), Cosme, N. M. D. (Intern), Hauschild, M. Z. (Intern), Henderson, A. (Ekstern), Huijbregts, M. (Ekstern), Jolliet, O. (Intern), Larsen, H. F. (Intern), van Zelm, R. (Ekstern)

Number of pages: 154

Publication date: 2013

### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

LC\_IMPACT\_D37\_AquatEutroph\_M41.pdf

### **Bibliographical note**

Deliverable report no. D3.7 (T3.1: Aquatic eutrophication) of the EU project LC-IMPACT (243827 FP7-ENV-2009-1) (Development and application of environmental Life Cycle Impact assessment Methods for imProved sustAinability Characterisation of Technologies).

Source: dtu

Source-ID: u::9285

Publication: Research - peer-review › Report – Annual report year: 2013

## Spatially-explicit LCIA endpoint model for marine eutrophication and application to future climatic-driven pressures

### General information

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Cosme, N. M. D. (Intern), Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Pages: 8-9

Publication date: 2013

### Host publication information

Title of host publication: All at Sea 2013 booklet : An integrated approach to research in the coastal zone

Publisher: University of York

Main Research Area: Technical/natural sciences

Conference: All at Sea 2013: An integrated approach to research in the coastal zone, York, United Kingdom, 04/07/2013 - 04/07/2013

Electronic versions:

All\_at\_Sea\_booklet.pdf

Links:

<http://www.york.ac.uk/conferences/allatsea/index.html>

### Relations

Activities:

All at Sea 2013: An integrated approach to research in the coastal zone

Source: dtu

Source-ID: u::9125

Publication: Research - peer-review > Conference abstract in proceedings – Annual report year: 2013

## Spatially-explicit LCIA endpoint model for marine eutrophication and application to future climatic-driven pressures

### General information

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Cosme, N. M. D. (Intern), Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Number of pages: 19

Publication date: 2013

### Publication information

Media of output: PowerPoint

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

Spatially\_explicit\_LCIA.pdf

Links:

<http://www.york.ac.uk/conferences/allatsea/index.html>

### Relations

Activities:

All at Sea 2013: An integrated approach to research in the coastal zone

Publication: Research > Sound/Visual production (digital) – Annual report year: 2013

### Case Study on Printed Matter in Denmark

The implementation of the EU REACH regulation will most probably promote substitution within sectors handling a lot of different chemicals such as the printing industry. With the aim of being at the cutting edge of this development, the Danish printing industry started up a substitution project in 2006. A major part of the work has been mapping the presence of chemicals, which are the potential candidates for substitution (e.g., PBT, CMR, vPvB, EDS). The mapping comprises a combination of a literature study and an investigation of the actual (2007) presence of candidate substances at 15 Danish printing houses including the examination of almost 900 MSDSs (i.e., products). Furthermore, a focused search in the Danish Product Register has been included. More than 200 of the mapped substances are candidates for substitution according to Danish legislation (List of Undesirable Substances) and about 60 of these substances fulfill one or more of the criteria (e.g., CMR, EDS) for the REACH Annex XIV candidate list (Authorisation List). This case study presents the results of the mapping of chemical substitution candidates some of which may be relevant regarding accumulation of additives/impurities in globally recycled paper.

### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Keywords: (Substances of very high concern (SVHC), REACH, Chemical substitution candidates, Printing industry, Recycled paper)

Pages: 167-181

Publication date: 2012

### Host publication information

Title of host publication: Global Risk-Based Management of Chemical Additives Volume 1: Production, Usage and Environmental Occurrence

Publisher: Springer

Series: The Handbook of Environmental Chemistry

Number: 18

Main Research Area: Technical/natural sciences

Links:

<http://www.springerlink.com/content/4t17237356k42856/>

Source: orbit

Source-ID: 280558

Publication: Research - peer-review › Book chapter – Annual report year: 2011

### Are Free Ion Activity Models Sufficient Alternatives to Biotic Ligand Models in Evaluating Metal Toxic Impacts in Terrestrial Environments?

Metal partitioning between solid and aqueous phases and speciation in soil pore water control the bioavailability of toxic forms of metals, while protons and base cations can mitigate metal ecotoxicity by competitive interactions with biotic ligands. The employment of BLMs to evaluate toxicity potential of metals in soils results in site-specific toxicity scores due to large variability of soil properties and differences in ionic composition. Unfortunately, terrestrial BLMs are available only for few metals and few organisms, thus their applicability to hazard ranking or toxic impact assessment is low and alternatives must be found. In this study, we compared published terrestrial BLMs and their potential alternatives such as free ion activity models (FIAM), for applicability in addressing metal toxic impacts in terrestrial environments. A set of 1300 soils representative for the whole world is employed to calculate EC50 and thereafter hazardous concentration HC50 (geometric mean of all EC50) for these terrestrial organisms, for which both TBLMs and FIAMs are available. Results showed that median HC50 for all soils predicted with BLMs range 2 and 3 orders of magnitude for copper and nickel, respectively. In all cases, predictions of FIAMs fall within the range of values predicted with BLMs, and toxicity ratio of copper to nickel is accurately predicted with both models. Thus, both models are able to distinguish between the two metals in terms of their average toxicity. Given that the calculated toxicity scores show large variability even for soils located in close proximity to each other, selection of FIAMs is also justified in deriving soil quality criteria. It remains to be investigated at what spatial scale the FIAMs are a good alternative to TBLMs in evaluating metal toxic impacts in terrestrial environments.

### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Owsianiak, M. (Intern), Rosenbaum, R. K. (Intern), Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Number of pages: 437

Publication date: 2011

Event: Poster session presented at Society of Environmental Toxicology and Chemistry : Navigating Environmental

Challenges: Historical Lessons Guiding Future Directions, Boston, MA, .

Main Research Area: Technical/natural sciences

Electronic versions:

[prod1132428440901.setac\\_north\\_america\\_2011\\_abstract\\_book\[1\].pdf](#)

### Bibliographical note

13–17 November

Source: orbit

Source-ID: 315558

Publication: Research › Poster – Annual report year: 2011

### Comparison of metal toxic impacts between aquatic and terrestrial organisms: is the free ion concentration a sufficient descriptor?

Characterization of metal toxic impacts in comparative risk assessment and life cycle impact assessment (LCIA) should take into account metal speciation and interactions with soil/water organic constituents, because these mechanisms control metal bioavailability and may influence their toxic properties. In a comparative context we are faced with the need

to characterise thousands of substances, but the limitation of the available data calls for reliable indicators suitable for extrapolation from the limited data that is available. Indeed, free metal ion concentration has in some cases been shown to be a sufficient indicator of metal toxicity for both aquatic and terrestrial species. With the aim of deriving extrapolations to predict terrestrial toxic impacts of metals from aquatic effect data, we compared copper toxicity of aquatic organisms with that of terrestrial organisms, testing the hypothesis that the free metal ion is an appropriate "general" descriptor of metal toxicity. Results for 128 laboratory tests on *Daphnia magna* exposed to copper ions (Cu<sup>2+</sup>) in water show that variation of several orders of magnitude are observed between the toxicity tests. These variations may be a result of the inability of the free metal ion concentration to reflect toxicity, as the presence of protons and other cations reacting with biological binding sites has been shown to affect the toxicity of copper to *D. magna*. Similar patterns, albeit with smaller variations, are observed for terrestrial organisms. Up to three orders of magnitude difference occur for the extreme case of barley (*Hordeum vulgare*). Given the scarcity of terrestrial effect data compared to aquatic data, reliable and transparent, mechanistic-based predictions of terrestrial toxic impacts from aquatic effect data would be an important step ahead in the context of LCIA or comparative risk. Here we demonstrate that the overall ability of the free metal ion to reflect toxicity of metals for aquatic and terrestrial organisms is limited. This has consequences if potential terrestrial toxic effects are based on extrapolations from aquatic data, because the use of more sophisticated models such as the Biotic Ligand Model (BLM) would be required. However, extrapolation models based on an improved free ion approach might still be a good proxy, particularly when the comparative nature of life cycle assessment is taken into account.

#### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Owsianiak, M. (Intern), Rosenbaum, R. K. (Intern), Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Number of pages: 67

Publication date: 2011

#### Host publication information

Title of host publication: SETAC Europe 21st Annual Meeting Abstract Book

Main Research Area: Technical/natural sciences

Conference: 21st SETAC Europe Annual Meeting, Milan, Italy, 15/05/2011 - 15/05/2011

Source: orbit

Source-ID: 277160

Publication: Research › Conference abstract in proceedings – Annual report year: 2011

#### Description of common methodology used in all case studies, following the ILCD methodology guide and the ISO standards for LCA (ISO 14040 and 14044)

This document describes common methodological issues for the case studies within LC-IMPACT. There will be five case studies in three areas performed within the project. The case studies are: Tomatoes, Margarine, Fish, Paper and printing and finally car manufacture and operation. In each case study several LCIA methods developed in other parts of LC-IMPACT will be applied and evaluated, but established LCIA methods will also be used and the studies shall be ILCD compliant. All case studies will follow the ILCD Handbook and this report describes common methodological choices needed and describes how data inventory is to be done and how deviations from the stated goals shall be managed and reported. A description of the external review is also presented.

#### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, SIK, Institut de Recerca i Tecnologia Agroalimentàries, USTUTT

Authors: Sonesson, U. (Ekstern), Anton, A. (Ekstern), Ohlau, K. (Ekstern), Larsen, H. F. (Intern)

Keywords: (LCA case studies, new LCIA methodology, common methodology)

Number of pages: 76

Publication date: 2011

#### Publication information

Original language: English

Series: EU FP7 project, deliverable

Number: 4.1

Main Research Area: Technical/natural sciences

Links:

<http://www.lc-impact.eu/>

Source: orbit

Source-ID: 280305

Publication: Research › Report – Annual report year: 2011

## Evaluering af CDV-værktøjet (Evaluation of the CDV-tool)

### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Keywords: (Critical dilution volume (CDV), scoring and ranking systems, eco-labeling, hazard assessment, chemicals,)

Number of pages: 20

Publication date: 2011

### Publication information

Place of publication: Lyngby

Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi

Volume: Rapport 2011, DTU Management

Edition: Rapport 2011

Original language: Danish

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 278562

Publication: Research › Report – Annual report year: 2011

## Kemikaliesubstitution i grafisk branche

The implementation of the EU REACH regulation will most probably promote substitution within sectors handling a lot of different chemicals like the printing industry. With the aim of being at the cutting edge of this development the Danish EPA together with the Danish printing industry and IPU are running a substitution project. A major part of the work has been mapping the presence of chemicals which are potential candidates for substitution (e.g. PBT, CMR, vPvB, EDS) within the Danish printing industry and this work was recently finished. The mapping comprises a combination of a literature study and an investigation of the actual (2007) presence of candidate substances at 15 Danish printing houses including the examination of almost 900 MSDS's (i.e. products). Furthermore, a focused search in the Danish Product Register has been included. More than 150 of the mapped substances are candidates for substitution according to Danish legislation (List of Undesirable Substances) and about 40 of these substances fulfil one or more of the criteria (e.g. CMR, EDS) for the REACH Annex XIV candidate list (authorisation). Three substances (phthalates) out of the first and recently published Annex XIV candidate list (in total 15 substances) were found in the Danish printing industry.

### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Grafisk

Arbejdsgiverforening

Authors: Larsen, H. F. (Intern), Bøgg, C. (Ekstern)

Keywords: (hazard ranking, REACH, chemical substitution, printing,, chemicals)

Number of pages: 75

Publication date: 2011

### Publication information

Publisher: Miljøstyrelsen

Original language: Danish

Series: Miljøprojekter

Number: 1354

Main Research Area: Technical/natural sciences

Electronic versions:

Kemikaliesub.pdf

Source: orbit

Source-ID: 274569

Publication: Research › Report – Annual report year: 2011

## LCA case studies: Textile and printed matter (paper)

### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Keywords: (Chemicals, Textiles, Printing industry, LCA, Recycling)

Publication date: 2011



### Publication information

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

RISKCYCLE\_Presentation\_Textile and printed matter LCA case studies; HFL\_DTU.pdf

Source: orbit

Source-ID: 285977

Publication: Research › Sound/Visual production (digital) – Annual report year: 2011

### Life cycle assessment and additives: state of knowledge

#### General information

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment, Leiden University, Swedish Environmental Research Institute

Authors: Larsen, H. F. (Intern), von der Voet, E. (Ekstern), Rydberg, T. (Ekstern)

Keywords: (printed matter, recycling, life cycle assessment, paper, additives, plastic,)

Number of pages: 56

Pages: 40-45

Publication date: 2011

#### Host publication information

Title of host publication: Proceedings of the 2nd RISKCYCLE workshop : Risk of chemical additives and recycled materials

Place of publication: Dresden

Editors: Bilitewski, B., Barceló, D., Darbra, R., Larsen, H. F., Rydberg, T., Benfenati, E., G., Grundmann, V.

Edition: 2nd RiskCycle Workshop

Main Research Area: Technical/natural sciences

Conference: RISKCYCLE workshop : Risk of chemical additives and recycled materials, Shenyang Institute of Aeronautical, Shenyang, China, 01/01/2010

Electronic versions:

RISKCYCLE - proceedings workshop Shenyang.pdf

Links:

<http://www.wadef.com/projects/riskcycle/results.php>

Source: orbit

Source-ID: 278572

Publication: Research › Article in proceedings – Annual report year: 2010

### Life cycle assessment and additives: state of knowledge

Concerns about possible toxic effects from additives/impurities accumulated in globally recycled waste/resources like paper and plastics was one of the main reasons for starting up the EU FP7 Coordination Action project RiskCycle ([www.wadef.com/projects/riskcycle](http://www.wadef.com/projects/riskcycle)). A key aim of the project is to identify research needs within this area focusing on both risk assessment (RA) and life cycle assessment (LCA). Besides the sectors on paper and plastics also lubricants, textiles, electronics and leather are included in RiskCycle. On plastics a literature review regarding the state of knowledge on additives/impurities in LCA has been performed within RiskCycle. Several inventory databases (LCI data) have been investigated and the result shows that most LCI databases use PlasticsEurope data for plastics production. Most of these data are aggregated and do not include additives. Regarding the production of additives only data on metals and DEHP was identified. As regards LCAs on plastics 110 papers has been reviewed. Only 25 of these mention additives but they are not included in the emissions list. Only a few studies include additives in the impact assessment and additives are never mentioned as important for the outcome. Regarding LCAs on printed matter (including paper) only a few studies have been done – mostly focusing on the energy part. However, one of the most recent and comprehensive studies actually include toxic impacts from chemical emissions – mostly printing chemicals like printing ink of which some components may accumulate in recycled paper. Even though recycling is included in this recent study there is no special focus on the additives/impurities in the recycled paper. Anyway, the study shows that potential toxic impacts from the production and use of chemicals like pigments, solvents, metals, AOX and biocides may play a very significant role in the impact profile of printed matter. Regarding the life cycle impact assessment (LCIA) part an investigation of the availability of characterisation factors (aquatic ecotox) for the about 17 additives/impurities to be included in RiskCycle have been done. These additives belong to 15 chemical groups/chemicals like PFOS, PFOA, NPAA, HBCDD, triclosan and more. The best practice LCIA “consensus” model USEtox was chosen. For only nine of the 17 substances characterisation factors exists and four of these are preliminary (interim). Regarding the rest, factors have to be calculated - if possible.

#### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Leiden University, Technical University of Denmark, Swedish Environmental Research Institute

Authors: Larsen, H. F. (Intern), von der Voet, E. (Ekstern), Van Oers L, L. (Ekstern), Yang, G. (Ekstern), Rydberg, T. (Ekstern)  
Keywords: (LCA, additives, recycling, waste)  
Publication date: 2011

#### Publication information

Original language: English  
Main Research Area: Technical/natural sciences  
Electronic versions:  
Extended abstract for RiskCycle presentation on LCA and additives Milano-2011-word.pdf  
SETAC; RISKCYCLE\_Presentation\_Life cycle assessment and additives; HFL\_DTU.pdf  
Links:  
[http://milano.setac.eu/milano/scientific\\_programme/downloads/?contentid=429](http://milano.setac.eu/milano/scientific_programme/downloads/?contentid=429)  
Source: orbit  
Source-ID: 277540  
Publication: Research › Sound/Visual production (digital) – Annual report year: 2011

#### Life cycle assessment (LCA) of printed matter: Potential “additives” in recycled paper

##### General information

State: Published  
Organisations: Quantitative Sustainability Assessment, Department of Management Engineering  
Authors: Larsen, H. F. (Intern)  
Keywords: (recycling, printed matter, substitution, additives, paper, LCA)  
Publication date: 2011

##### Publication information

Original language: English  
Main Research Area: Technical/natural sciences  
Electronic versions:  
Extended abstract-hfl.pdf  
Source: orbit  
Source-ID: 277532  
Publication: Research › Sound/Visual production (digital) – Annual report year: 2011

#### Life cycle assessment (LCA) of printed matter: Potential “additives” in recycled paper

##### General information

State: Published  
Organisations: Department of Management Engineering, Quantitative Sustainability Assessment  
Authors: Larsen, H. F. (Intern)  
Keywords: (substitution of hazardous chemicals, printing industry inventory, REACH, printed matter, life cycle assessment , paper, substances of very high concern, additives, recycling.)  
Number of pages: 50  
Pages: 35-41  
Publication date: 2011

##### Host publication information

Title of host publication: Proceedings of the 3rd RISKCYCLE workshop : Environmental and health risks of chemical additives and recycling materials  
Place of publication: Dresden  
Editors: Bilitewski, B., Barceló, D., Darbra, R., Larsen, H. F., Rydberg, T., Benfenati, E., G., Grundmann, V.  
Edition: 3rd RiskCycle Workshop  
Main Research Area: Technical/natural sciences  
Conference: RISKCYCLE workshop : Environmental and health risks of chemical additives and recycling materials, Casa da Ciencia da UFRJ, Rio de Janeiro, Brazil, 01/01/2011  
Electronic versions:  
RISKCYCLE - proceedings workshop Rio.pdf  
Links:  
<http://www.wadef.com/projects/riskcycle/results.php>  
Source: orbit  
Source-ID: 278611  
Publication: Research › Article in proceedings – Annual report year: 2011

### **Rådgivningsmetoder til kemikaliesubstitution i grafisk produktion**

A number of industry specific methods for chemical substitution have been developed and tested in the project 'Counseling methods for chemical substitution'. The result of this work is described in this report and has in addition been integrated in a prototype for an electronic auxiliary tool. This report and particularly the final version of the electronic auxiliary tool will be a help to both the printing companies and to the industry's counselors, who work with the often difficult process of chemical substitution.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Danish Meat Association

Authors: Hansen, P. K. (Ekstern), Larsen, H. F. (Intern), Beck, S. E. (Ekstern)

Keywords: (REACH, printing houses, chemical substitution, printing, occupational health and safety, chemicals)

Number of pages: 81

Publication date: 2011

#### **Publication information**

Publisher: Miljøstyrelsen

Original language: Danish

Series: Miljøprojekter

Number: 1355

Main Research Area: Technical/natural sciences

Electronic versions:

978-87-92708-81-6.pdf

Source: orbit

Source-ID: 274570

Publication: Research › Report – Annual report year: 2011

### **Review on methodology for LCIA of marine eutrophication**

As part of the ongoing EU FP7 project LC-Impact ([www.lc-impact.eu](http://www.lc-impact.eu)) new life cycle impact assessment (LCIA) methods are going to be developed and tested on industry cases. Among the life cycle assessment (LCA) impact categories in focus are aquatic eutrophication. As related to especially the marine environment very few and restricted attempts have yet been done on trying to include eutrophication in LCA. The aim of LC-Impact is to develop both a global and a spatial (and temporal) differentiated model, as both central fate processes, sensitivities of receiving environments (e.g. differences in limiting nutrient and variations in this over the year) and the resulting damage can show important spatial variations. Both midpoint and endpoint (damage) modelling are included and the aim is to base the damage modelling on dose-response curves expressing the correlation between the (increase in) nutrient concentration and the potentially affected fraction of species in the marine ecosystem. This poster will present a review of the very limited existing attempts on how to include marine eutrophication in LCA and discuss alternative methodologies on how to model the environmental mechanism of this impact category.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Keywords: (Damage modeling, Review, LCIA methodology, Marine eutrophication)

Number of pages: 1

Publication date: 2011

Event: Poster session presented at 21st SETAC Europe Annual Meeting, Milan, Italy.

Main Research Area: Technical/natural sciences

Electronic versions:

Poster; Review on LCIA of marine eutrophication-SETAC-Milan-May-2011.pdf

Links:

[http://milano.setac.eu/milano/scientific\\_programme/downloads/?contentid=429](http://milano.setac.eu/milano/scientific_programme/downloads/?contentid=429)

Source: orbit

Source-ID: 277539

Publication: Research › Poster – Annual report year: 2011

### **Towards a Standard Method for Life Cycle Assessments of Wastewater Treatment**

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Catalan Institute for Water Research, GHD Pty Ltd., University of Michigan, University of Santiago de Compostela, Illinois Institute of Technology

Authors: Corominas, L. (Ekstern), Foley, J. (Ekstern), Guest JS, J. (Ekstern), Hospido A, A. (Ekstern), Larsen, H. F. (Intern), Shaw, A. (Ekstern)

Keywords: (Sewage, Guidelines, LCA, Review, Sludge, Standardisation)

Publication date: 2011

#### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

Corominasetal\_Watermatex2011\_ppt.pdf

Source: orbit

Source-ID: 280806

Publication: Research › Sound/Visual production (digital) – Annual report year: 2011

### **Towards a Standard Method for Life Cycle Assessments of Wastewater Treatment**

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Catalan Institute for Water Research, GHD Pty Ltd., University of Michigan, University of Santiago de Compostela, Illinois Institute of Technology

Authors: Corominas, L. (Ekstern), Foley, J. (Ekstern), Guest, J. (Ekstern), Hospido, A. (Ekstern), Larsen, H. F. (Intern), Shaw, A. (Ekstern)

Keywords: (sludge, Guidelines, LCA, Review, standardisation)

Number of pages: 281

Pages: 168-175

Publication date: 2011

#### **Host publication information**

Title of host publication: Proceedings of the 8th IWA Symposium on Systems Analysis and Integrated Assessment

Publisher: IWA Publishing Company

Main Research Area: Technical/natural sciences

Conference: Watermatex, San Sebastian, Spain, 20-22 June, 01/01/2011

Source: orbit

Source-ID: 280807

Publication: Research › Article in proceedings – Annual report year: 2011

### **USEtox fate and ecotoxicity factors for comparative assessment of toxic emissions in Life Cycle Analysis: Sensitivity to key chemical properties**

The USEtox model was developed in a scientific consensus process involving comparison of and harmonization between existing environmental multimedia fate models. For freshwater ecosystem toxicity, it covers the entire impact pathway, i.e., transforming a chemical emission into potential impacts based on quantitative modeling of fate, exposure, and ecotoxicity effects. Taken together, these are represented as chemical-specific characterization factors (CFs). Through analysis of freshwater CFs for approximately 2500 organic chemicals, with special focus on a subset of chemicals with characteristic properties, this work provides understanding of the basis for calculations of CFs in USEtox. In addition, it offers insight into the chemical properties and critical mechanisms covering the continuum from chemical emission to freshwater ecosystem toxicity. For an emission directly to water, the effect factor, which is obtained from laboratory measurements of substance toxicity to different phyla, strongly controls freshwater ecotoxicity, with a range of up to 10 orders of magnitude. Chemical-specific differences in multimedia transfer influence the CF for freshwater emissions by less than two orders of magnitude. However, for an emission to air or soil, differences in chemical properties may decrease the CF by up to 10 orders of magnitude, as a result of intermedia transfer and degradation. This result brings new clarity to the relative contributions of fate and freshwater ecotoxicity to the overall characterization factor.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, University of Michigan, Radboud Universiteit, École Polytechnique de Montréal, University of California at Berkeley, Cycleco

Authors: Andrew D, H. (Ekstern), Hauschild, M. Z. (Intern), Van de Meent, D. (Ekstern), Huijbregts, M. A. (Ekstern), Larsen, H. F. (Intern), Margni, M. (Ekstern), McKone, T. E. (Ekstern), Payet, J. (Ekstern), Rosenbaum, R. K. (Intern), Jolliet, O. (Ekstern)

Keywords: (Characterization factors, Fate modeling, USEtox., Life Cycle Impact Assessment, Freshwater ecotoxicity, Model comparison)

Pages: 710-727  
Publication date: 2011  
Main Research Area: Technical/natural sciences

#### **Publication information**

Journal: International Journal of Life Cycle Assessment

Volume: 16

Issue number: 8

ISSN (Print): 0948-3349

Ratings:

BFI (2015): BFI-level 2

Scopus rating (2015): 1.58 1.453

BFI (2014): BFI-level 2

Scopus rating (2014): 1.799 1.743

BFI (2013): BFI-level 2

Scopus rating (2013): 1.701 1.983

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 2

Scopus rating (2012): 1.528 1.72

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 2

Scopus rating (2011): 1.605 1.729

ISI indexed (2011): ISI indexed yes

BFI (2010): BFI-level 2

Scopus rating (2010): 1.471 1.884

BFI (2009): BFI-level 2

Scopus rating (2009): 1.228 1.557

BFI (2008): BFI-level 2

Scopus rating (2008): 0.892 1.338

Scopus rating (2007): 0.803 1.237

Scopus rating (2006): 0.63 1.382

Scopus rating (2005): 0.646 1.755

Scopus rating (2004): 0.641 1.488

Scopus rating (2003): 0.502 1.803

Scopus rating (2002): 0.295 0.98

Scopus rating (2001): 0.492 1.648

Scopus rating (2000): 1.12 2.308

Scopus rating (1999): 0.429 1.408

Original language: English

DOIs:

10.1007/s11367-011-0294-6

Source: orbit

Source-ID: 277473

Publication: Research - peer-review › Journal article – Annual report year: 2011

#### **Assessment of environmental sustainability of technologies using Life Cycle Analysis**

##### **General information**

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment, Université Laval, Swiss Federal Institute of Aquatic Science and Technology

Authors: Corominas, L. (Ekstern), Flores-Alsina, X. (Ekstern), Vanrolleghem, P. A. (Ekstern), Larsen, H. F. (Intern), Joss, A. (Ekstern), Siegrist, H. (Ekstern)

Keywords: (LCA, waste water treatment, ICA, environmental sustainability, anammox, modelling waste water treatment, GHG)

Publication date: 2010

##### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

WWTmod2010-Lluis-hfl.pdf

### **Bibliographical note**

March 28-30, 2010, Mont-Sainte-Anne, Quebec, Canada

Source: orbit

Source-ID: 267095

Publication: Research > Sound/Visual production (digital) – Annual report year: 2010

### **Case study on printed matter: Including chemical-related impact categories in LCA on offset printed matter**

Introduction Existing product Life Cycle Assessments (LCA's) on offset printed matter all point at paper as the overall dominating contributor to the impacts from the life-cycle of this category of products. This dominating role of paper is primarily founded in the energy-related impact categories global warming, acidification and eutrophication. The studies focus on energy consumption including the emissions and impact categories related to energy. The chemical-related impact categories comprising ecotoxicity and human toxicity are not included at all or only to a limited degree. In this paper we include these chemical-related impact categories by making use of some of the newest knowledge about emissions from the production at the printing industry combined with knowledge about the composition of the printing materials used during the production of offset printed matter. This paper is based on the dissertation "Assessment of chemical emissions in life cycle impact assessment" (Larsen 2004) and the paper "Life-cycle assessment of offset printed matter with EDIP97 – how important are emissions of chemicals?" (Larsen et al. 2009). Goal and scope The goal of the study is to identify the distribution of potential environmental impacts and consumption of resources along the life cycle of a generic printed matter produced on a model sheet feed offset printing industry in Europe. Main activities at all stages in the life cycle are covered. However special focus is on the production stage but upstream emissions assessed to be of possible significant importance are included (e.g. estimated emissions from pigment production) or handled in the sensitivity analysis. The functional unit is 1 ton of sheet feed offset produced printed matter, i.e. printed communication covering books, pamphlets etc. As time scope for the production stage 1990 – 2002 is chosen and as technological scope mainly modern technology (not state-of-the-art) used at least in Northern Europe is used. Marginal approaches are used for production of electricity (natural gas) and paper production (virgin fibres) as the main approach i.e. in the reference scenario. In all other cases an average approach is used. The consumption of raw materials at the model printing industry is mainly based on average values for 10 – 70 Swedish and Danish offset printing industries. The range in the consumption of the most important raw materials is typically well below or just above a factor of about 10. Method The EDIP97 LCA method is used. The impact assessment comprises classification, characterisation, normalisation and weighting. Danish/global normalisation references and weighting factors are used in the reference scenario and European/global ones are used for sensitivity analysis. The weighting factors for the impact categories are based on political reduction targets. Conclusion The distribution of potential environmental impacts along the life cycle of a generic printed matter produced on a model sheet feed offset printing industry in Europe has been identified and shown in Figure 1 (grey bars). The effect of including the chemical related impact categories is substantial as shown in Figure 1 (black bars), e.g. the importance of paper is reduced from 67% to 31% and the importance of printing increased from 10% to 41%. Sensitivity analysis including e.g. alternative normalisation references and alternative paper disposals (land fill), does not change the overall conclusion significantly. Furthermore, the case study shows that, even though this is a special case where the potential fate and toxicity of relatively many of the chemical emissions are known, making it possible to characterize or exclude them as potential significant contributing, only 25% - 37% of the total number of emissions is characterized. For many of the non-characterized emissions sufficient data to estimate characterisation factors do not exist. Depending on the scope, this fact seems to be of general validity in LCA studies – at least for those including many chemical emissions like studies on all types of printed matter and textiles – and this weakens the credibility of the results. Possible impacts due to (accumulated) additives and/or impurities in recycled materials like paper is not included in this study. Taking these issues into account will most probably increase the importance of the chemical related impact categories in the life cycle of printed matter. References Larsen HF, Hansen MS, Hauschild M (2009). Life-cycle assessment of offset printed matter with EDIP97 – how important are emissions of chemicals? *J Clean Prod* 17, 115 – 128. Larsen HF (2004). Assessment of chemical emissions in life cycle impact assessment - focus on low substance data availability and ecotoxicity effect indicators. Ph.D. Thesis, October 2004. Department of Manufacturing, Engineering and Management. Technical University of Denmark. <http://www.tempo.ipl.dtu.dk/ipl/upload/publ/PhD-thesis-rev.pdf> Figure 1 Comparison of weighted LCA profiles with or without chemical related impact categories included (percentage of total, milli-person-equivalents-targeted, mPET). The avoided energy consumptions and emissions due to incineration and recycling of paper are allocated to "Paper (net)".

### **General information**

State: Published

Organisations: Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Keywords: (LCA; Chemicals; LCIA; Printed matter)

Publication date: 2010

### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

Microsoft PowerPoint - RISKCYCLE\_Presentation\_Case study on printed materials HFL\_DTU.pdf

Links:

<http://www.wadef.com/projects/riskcycle/>

Source: orbit

Source-ID: 262215

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

#### **Deliverable 4.3 Decision support guideline based on LCA and cost/efficiency assessment**

The environmental sustainability assessments described in this report is based on life cycle assessments (LCA) of selected waste water treatment technology (WWTT) cases included in NEPTUNE. The basic approach in these assessments (avoided against induced impacts) is described in Deliverable 4.1 (Larsen et al. 2007) and other methodological issues (e.g. normalization and weighting) in Deliverable 4.2 (Larsen et al. 2009). The basic approach is illustrated in a simplified way for the case ozonation in Figure 2.1. The technologies investigated include conventional WWT (reference), ozonation, sand filtration, PAC addition, anammox, sludge incineration (reference), other sludge inertization technologies (wet oxidation, high temperature pyrolysis, gasification) and sludge triage (including sludge disintegration technologies, i.e. thermal hydrolysis and ultrasound disintegration). They are divided into four clusters related to the main purpose of the treatment, e.g. nutrient removal or micropollutant removal. All are assessed within the cluster by comparing with the reference or by looking at induced versus avoided environmental impacts potentials originated from the various emissions and flows inventoried. Figure 2.1 Do we induce more environmental impact than we avoid by introducing a new waste water treatment technology (sub-optimisation)? The study is based as much as possible on data obtained directly from NEPTUNE partners for the physical and functional inventory. In particular, the functional inventory of cluster 1 on micropollutant removal, tracks 22 organic micropollutants (pharmaceuticals) that have been sampled in different WWTTs by NEPTUNE partners. The resulting inventory is then modelled according to the EDIP97 methodology on the GaBi LCA modelling software, i.e. GaBi 4 (PE 2008), with EcoInvent 2.0 database integrated (EcoInvent 2007).

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hansen, P. A. (Intern), Boyer-Souchet, F. (Ekstern)

Keywords: (Environmental sustainability, LCA, EDIP, Sludge, Micropollutants, Waste water)

Number of pages: 163

Publication date: 2010

#### **Publication information**

Original language: English

Series: EU FP6 project, deliverable

Number: 4.3

Main Research Area: Technical/natural sciences

Electronic versions:

D4.3.pdf

Links:

[http://www.eu-neptune.org/Publications%20and%20Presentations/index\\_EN](http://www.eu-neptune.org/Publications%20and%20Presentations/index_EN)

Source: orbit

Source-ID: 267059

Publication: Research › Report – Annual report year: 2010

#### **Environmental sustainability of waste water ozonation**

The EU FP6 NEPTUNE project is related to the EU Water Framework Directive and the main goal is to develop new and optimize existing waste water treatment technologies (WWTT) and sludge handling methods for municipal waste water. Besides nutrients, a special focus area is micropollutants (e.g. pharmaceuticals, heavy metals and endocrine disrupters). As part of this work a holistic based prioritisation among technologies and optimisations have been done. Tools for this prioritisation include life cycle assessment (LCA) and cost/efficiency. The LCA is performed as a comparative LCA and the concept of induced impacts as compared to avoided impacts is introduced in the life cycle impact assessment (LCIA) part. A relatively high number of micropollutants, especially pharmaceuticals, have been included. Furthermore, as novel approaches, preliminary methodologies for impact categories on pathogens and whole effluent toxicity have been developed. About 15 different waste water and sludge treatment technologies (or combinations) have been assessed. This paper will present the LCA results from running the induced versus avoided impact approach on one of the WWTTs, i.e. ozonation.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hansen, P. A. (Intern)

Keywords: (waste water, ozonation, LCA,, Sustainability)

Number of pages: 1

Publication date: 2010

Event: Poster session presented at 20th SETAC Europe Annual Meeting, Sevilla, Spain.

Main Research Area: Technical/natural sciences

Electronic versions:

Poster Sustainability of ozonation-SETAC-Sevilla-May-2010.pdf

Source: orbit

Source-ID: 262514

Publication: Research › Poster – Annual report year: 2010

### **Environmental sustainability of wastewater sludge treatments**

The European Water Framework Directive addresses the issue of pollution from urban waste water and is thereby changing the scope of sewage treatment. As part of this process, the Neptune project (EU, FP6) focuses on developing new and upgrading existing technologies of waste water and sludge treatment for municipal waste water. A special focus area in Neptune is sludge handling because the sludge amount is expected to increase due to advanced waste water treatment. The main sludge processing methods assessed in Neptune can be divided into two categories: disintegration processes before anaerobic digestion (thermal hydrolysis and ultrasound disintegration) and inertisation processes performed at high temperatures (incineration, pyrolysis, gasification, wet oxidation) but they all aim at volume reduction and removal of biodegradable compounds before safe sludge disposal or reuse of its resources. As part of a sustainability assessment (or "best practice evaluation"), a comparison between the existing and new sludge handling techniques have been done by use of life cycle assessment (LCA). The concept of induced impacts as compared to avoided impacts when introducing a new sludge treatment technology is used for the environmental comparison. Emissions from the treatment of the sludge as well as energy consumption and production, chemical consumption, infrastructures and transport are taken into account. This poster will present the results of LCA's performed on different inertisation technologies. Incineration is used as the reference process, as it is the only existing well-developed technology, while other techniques like pyrolysis and gasification are relatively new, and only exist at lab-scale or pilot-plant scale.

### **General information**

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment, Technical University of Denmark

Authors: Boyer-Souchet, F. (Ekstern), Larsen, H. F. (Intern)

Keywords: (Environmental sustainability, sludge inertisation, LCA, waste water sludge treatment technologies)

Publication date: 2010

Event: Poster session presented at Neptune and Innowatech End User Conference, Ghent, Belgium.

Main Research Area: Technical/natural sciences

Electronic versions:

Poster\_ Sustainability of sludge treatment final.jpg

### **Bibliographical note**

27th January

Source: orbit

Source-ID: 258011

Publication: Research › Poster – Annual report year: 2010

### **From emission to ecotoxicity: comparative assessment of fate and ecotoxicity in LCA using USEtox**

The USEtox model was developed in a scientific consensus process involving comparison of and harmonization between existing environmental multimedia fate models. For life cycle impact assessment, USEtox may be used as a comparative tool for ecosystem and human toxicity. As a characterization model, it covers the entire impact pathway transforming a chemical emission into potential impacts on freshwater ecosystems based on quantitative modeling of fate, exposure and ecotoxicity effects. Taken together, these are represented as chemical-specific characterization factors (CFs). In the case of freshwater ecotoxicity, impacts are measured as potentially affected or disappeared species [PAF m<sup>3</sup>-day / kgemitted]. Through analysis of the freshwater CFs of over three thousand organic chemicals, this work provides insight into the chemical properties that most strongly influence freshwater ecosystem toxicity for a variety of emission scenarios. Furthermore, the analysis addresses the influence of chemical properties along the emission-fate-exposure-impact chain of events. The main trends are identified using results for the entire dataset of chemicals, and typical patterns are illustrated for a small selection of chemicals with characteristic combinations of properties. For an emission directly to water, the effect factor, which is obtained from laboratory measurements of substance toxicity to different trophic levels, strongly controls toxicity. Multimedia transfer affects the CF for these emissions by less than two orders of magnitude. However, for emission to air or soil, intermedia transfer and degradation may decrease the CF by up to 10 orders of magnitude. This result shows the importance of the Henry's law constant, the organic carbon and octanol-water partitioning coefficient, the degradation half-life in various media, and the treatment of intermittent rain in the model. The



interplay between these parameters and the model, which assumes a typical ratio of water to land surface area, shows that direct air to water transfer is less important for many hydrophilic chemicals than might be suspected. As a result, for some compounds, second-order transfers, eg., from air to soil to water, are relatively more important. USEtox addresses some of the pressing problems in current life cycle impact assessment of chemical emissions by providing a consensus model that can calculate transparent chemical-specific characterization factors.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, National Institute for Public Health and Environment, University of Michigan, Radboud Universiteit, Interuniversity Research Centre for the Life Cycle of Products, Processes and Services, University of California at Berkeley, École Polytechnique Fédérale de Lausanne

Authors: Hauschild, M. Z. (Intern), Van de Meent, D. (Ekstern), Henderson, A. (Ekstern), Huibregts, M. A. (Ekstern), Larsen, H. F. (Intern), Margni, M. (Ekstern), McKone, T. E. (Ekstern), Payet, J. (Ekstern), Rosenbaum, R. K. (Intern), Jolliet, O. (Ekstern)

Keywords: (LCIA, LCA, aquatic ecotoxicity, USEtox)

Publication date: 2010

#### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Links:

<http://portland.setac.org/node/5>

Source: orbit

Source-ID: 268646

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

#### **Full-scale ozonation of WWTP effluent followed by sandfiltration**

##### **General information**

State: Published

Organisations: Department of Management Engineering, Swiss Federal Institute of Aquatic Science and Technology, Frankfurt University

Authors: Zimmermann, S. (Ekstern), Bocker, S. (Ekstern), Escher, B. (Ekstern), Hansen, P. A. (Intern), Hollender, J. (Ekstern), Koepke, S. (Ekstern), Krauss, M. (Ekstern), Larsen, H. F. (Intern), Magdeburg, A. (Ekstern), McArdell, C. (Ekstern), Oehlmann, J. (Ekstern), Ort, C. (Ekstern), Rensch, D. (Ekstern), Siegrist, H. (Ekstern), Singer, H. (Ekstern), Stalter, D. (Ekstern), Suter, M. (Ekstern), von Gunten, U. (Ekstern)

Publication date: 2010

##### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Links:

[http://www.eu-neptune.org/index\\_EN](http://www.eu-neptune.org/index_EN)

##### **Bibliographical note**

27th January

Source: orbit

Source-ID: 258019

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

#### **Inclusion of ecotoxicity in LCA. Ozonation and PAC addition processes as case examples**

##### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Keywords: (LCA, LCIA, ecotoxicity, waste water, micropollutants, environmental sustainability, ozonation, PAC addition)

Publication date: 2010

##### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Links:

[http://www.eu-neptune.org/index\\_EN](http://www.eu-neptune.org/index_EN)

#### **Bibliographical note**

March 25-26, 2010 at University Laval (ModelEAU), Quebec, Canada

Source: orbit

Source-ID: 259653

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

#### **Life cycle assessment and additives: state of knowledge**

##### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Leiden University, Swedish Environmental Research Institute

Authors: Larsen, H. F. (Intern), van der Voet, E. (Ekstern), Rydberg, T. (Ekstern)

Keywords: (printed matter, plastics, paper, LCA, additives, LCIA)

Publication date: 2010

##### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

RISKCYCLE\_Presentation\_Life cycle assessment and additives; HFL\_DTU.pdf

Source: orbit

Source-ID: 269352

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

#### **Putting micropollutants, energy, nutrients and GHG emissions on an equal basis: An LCA approach**

##### **General information**

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Larsen, H. F. (Intern)

Keywords: (LCA, LCIA, environmental sustainability, micropollutants, nutrients, ozonation, sand filtration, waste water, normalisation, weighting)

Publication date: 2010

##### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

WWTmod2010-hfl.pdf

##### **Bibliographical note**

March 28-30, 2010, Mont-Sainte-Anne, Quebec, Canada

Source: orbit

Source-ID: 259655

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

#### **Simplified methodology for inclusion of climate parameters in chemical prioritization as applied in life cycle impact assessment and risk assessment – PBT(+C) prioritization**

##### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Aarhus University

Authors: Birkved, M. (Intern), Larsen, H. F. (Intern), Gustavson, K. (Forskerdatabase), Hauschild, M. Z. (Intern)

Publication date: 2010

Event: Poster session presented at 20th SETAC Europe Annual Meeting, Sevilla, Spain.

Main Research Area: Technical/natural sciences

Publication: Research - peer-review › Poster – Annual report year: 2010

#### **Sludge inertisation with high temperature pyrolysis**

### **General information**

State: Published

Organisations: Department of Management Engineering, Swiss Federal Institute of Aquatic Science and Technology, Technical University of Denmark

Authors: Miladinovic, N. (Ekstern), Boyer-Souchet, F. (Ekstern), Larsen, H. F. (Intern)

Publication date: 2010

### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Links:

[http://www.eu-neptune.org/index\\_EN](http://www.eu-neptune.org/index_EN)

### **Bibliographical note**

27th January

Source: orbit

Source-ID: 258018

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

## **The use of life cycle assessment (LCA) for environmental sustainability assessment of waste water treatment systems: Focus on micropollutant removal and ecotoxicity**

### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Keywords: (LCIA, environmental sustainability, waste water treatment technologies, pharmaceuticals, ecotoxicity)

Publication date: 2010

### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

CRTE Luxembourg 6-7-2010hfl.pdf

Source: orbit

Source-ID: 264834

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

## **Use of control to improve nutrient removal: Perspectives (LCA and fault-tolerant control)**

### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Université Laval

Authors: Corominas, L. (Ekstern), Flores-Alsina, X. (Ekstern), Larsen, H. F. (Intern), Vanrolleghem, P. A. (Ekstern)

Keywords: (LCA, fault-control, waste water treatment, nutrient removal, sensors)

Publication date: 2010

### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Links:

[http://www.eu-neptune.org/index\\_EN](http://www.eu-neptune.org/index_EN)

### **Bibliographical note**

March 25-26, 2010 at University Laval (ModelEAU), Quebec, Canada

Source: orbit

Source-ID: 259656

Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

## **Deliverable 4.2: Methodology for including specific biological effects and pathogen aspects into LCA**

As described in deliverable 4.1 (Larsen et al. 2007) NEPTUNE is using two main types of life cycle impact assessment (LCIA) methodologies when doing LCA studies on the waste water treatment technologies included. The basic methodology is the well known existing EDIP97 methodology (Wenzel et al. 1997, Hauschild and Wenzel 1998) for which the impact assessment on toxicity is PNEC based. However, in order to include the newest development on especially best available practice as regards ecotoxicity a new revised and updated EDIP 200X LCIA methodology has been

developed. A first draft of this methodology is presented here. Furthermore, special issues related to waste water have been addressed by including novel development on LCIA methodology for possible impact from pathogens and whole effluent toxicity. Special focus is also allocated to micropollutants with specific toxic mode of action (i.e. endocrine disruptors) and the possibilities and relevance of including impact categories on land use and site-specific assessments have been addressed. Further, the special problems on how to deal with land fill and how to do normalization and weighting of impact potentials are also dealt with. The problem with possible bias in normalization references is especially addressed.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Olsen, S. I. (Intern), Hauschild, M. Z. (Intern), Laurent, A. (Intern)

Keywords: (Whole Effluent Toxicity, EDIP 200X, Endocrine disrupters, Normalisation, Pathogens, LCIA methodology, Land fill)

Number of pages: 111

Publication date: 2009

#### **Publication information**

Original language: English

Series: EU FP6 project, deliverable

Number: 4.2

Main Research Area: Technical/natural sciences

Electronic versions:

D4.2.pdf

Source: orbit

Source-ID: 250014

Publication: Research › Report – Annual report year: 2009

#### **Environmental sustainability of ozonating municipal waste water**

The EU FP6 NEPTUNE project is related to the EU Water Framework Directive and the main goal is to develop new and optimize existing waste water treatment technologies (WWTT) and sludge handling methods for municipal waste water. Besides nutrients, a special focus area is micropollutants (e.g. pharmaceuticals, heavy metals and endocrine disrupters). As part of this work a holistic based prioritisation among technologies and optimisations is to be done. Tools for this prioritisation include life cycle assessment (LCA) and cost/efficiency. The LCA is performed as a comparative LCA and the concept of induced impacts as compared to avoided impacts is introduced in the life cycle impact assessment (LCIA) part. Furthermore, as novel approaches, potential ecotoxicity impact from a high number of micropollutants and the potential impact from pathogens (and whole effluent toxicity) are to be included. In total more than 20 different waste water and sludge treatment technologies are to be assessed. This paper will present the preliminary LCA results from running the induced versus avoided impact approach (mainly based on existing LCIA methodology) on one of the WWTTs, i.e. ozonation.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hansen, P. A. (Intern)

Keywords: (sand filter, waste water, ozonation, LCA, sustainability, LCIA)

Number of pages: 355

Publication date: 2009

Event: Poster session presented at 19th Annual meeting of Society of Environmental Toxicology and Chemistry, Göteborg, Sweden.

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 244445

Publication: Research › Poster – Annual report year: 2009

#### **Life cycle assessment of advanced waste water treatment: Micropollutant removal - ozonation as example**

The EU FP6 NEPTUNE project is related to the EU Water Framework Directive and the main goal is to develop new and optimize existing waste water treatment technologies (WWTT) and sludge handling methods for municipal waste water. Besides nutrients, a special focus area is micropollutants (e.g. pharmaceuticals, heavy metals and endocrine disrupters). As part of this work a holistic based prioritisation among technologies and optimisations is to be done. Tools for this prioritisation include life cycle assessment (LCA) and cost/efficiency. The LCA is performed as a comparative LCA and the concept of induced impacts as compared to avoided impacts is introduced in the life cycle impact assessment (LCIA) part. Furthermore, as novel approaches, potential ecotoxicity impact from a high number of micropollutants and the potential impact from pathogens (and whole effluent toxicity) are to be included. In total more than 20 different waste water and sludge treatment technologies are to be assessed. This paper will present the preliminary LCA results from running the

induced versus avoided impact approach (mainly based on existing LCIA methodology) on one of the advanced treatment technologies, i.e. ozonation.

#### **General information**

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Larsen, H. F. (Intern), Hansen, P. A. (Intern)

Keywords: (LCA, LCIA, waste water, environmental sustainability, ozonation, pharmaceuticals, sand filtration)

Publication date: 2009

#### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 242177

Publication: Research › Sound/Visual production (digital) – Annual report year: 2009

#### **Life cycle assessment of offset printed matter with EDIP97: – how important are emissions of chemicals?**

Existing product life cycle assessment (LCA) studies on offset printed matter all point at paper as the overall dominating cause of environmental impacts. All studies focus on energy consumption and the dominating role of paper is primarily based on the energy-related impact categories global warming, acidification and nutrient enrichment. Ecotoxicity and human toxicity, which are related to emissions of chemicals etc., are only included to a limited degree or not at all. In this paper we include the impacts from chemicals emitted during the life cycle of sheet fed offset printed matter. This is done by making use of some of the newest knowledge about emissions from the production at the printing industry combined with knowledge about the composition of the printing materials used. In cases with available data also upstream emissions from the production of printing materials are included. The results show that inclusion of the chemical emission-related impacts makes the EDIP97 impact profile of sheet fed offset products much more varied, as well for the normalised profiles as for the profiles weighted by distance to political environmental targets. Especially the ecotoxicity impact potential related to the production stage may contribute significantly, and the use of paper no longer becomes the overall dominating factor driving the environmental impacts.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hansen, M. S. (Intern), Hauschild, M. Z. (Intern)

Keywords: (Printed matter, Chemicals, Analysis of robustness, LCA, Chemical emission-related impact categories)

Pages: 115-128

Publication date: 2009

Main Research Area: Technical/natural sciences

#### **Publication information**

Journal: Journal of Cleaner Production

Volume: 17

Issue number: 2

ISSN (Print): 0959-6526

Ratings:

BFI (2015): BFI-level 2

BFI (2014): BFI-level 2

BFI (2013): BFI-level 2

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 2

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 2

ISI indexed (2011): ISI indexed yes

BFI (2010): BFI-level 2

BFI (2009): BFI-level 2

BFI (2008): BFI-level 2

Original language: English

DOIs:

10.1016/j.jclepro.2008.03.006

Source: orbit

Source-ID: 213594

Publication: Research - peer-review › Journal article – Annual report year: 2009

## Miljømæssig bæredygtighed ved spildevandsbehandling

### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Pages: 16-17

Publication date: 2009

Main Research Area: Technical/natural sciences

### Publication information

Journal: EVA : Erfaringsudveksling i vandmiljøteknikken

Volume: 22

Issue number: 2 / Maj

ISSN (Print): 1901-3663

Ratings:

ISI indexed (2013): ISI indexed no

ISI indexed (2012): ISI indexed no

ISI indexed (2011): ISI indexed no

Original language: Danish

Links:

[http://www.evanet.dk/pdf/blade/EVA\\_blad%20maj%202009.pdf](http://www.evanet.dk/pdf/blade/EVA_blad%20maj%202009.pdf)

Source: orbit

Source-ID: 244661

Publication: Communication › Journal article – Annual report year: 2009

### Substitution within the Danish printing industry

The implementation of the EU REACH regulation will most probably promote substitution within sectors handling a lot of different chemicals like the printing industry. With the aim of being at the cutting edge of this development the Danish EPA together with the Danish printing industry and IPU are running a substitution project. A major part of the work has been mapping the presence of chemicals which are potential candidates for substitution (e.g. PBT, CMR, vPvB, EDS) within the Danish printing industry and this work was recently finished. The mapping comprises a combination of a literature study and an investigation of the actual (2007) presence of candidate substances at 15 Danish printing houses including the examination of almost 900 MSDS's (i.e. products). Furthermore, a focused search in the Danish Product Register has been included. More than 150 of the mapped substances are candidates for substitution according to Danish legislation (List of Undesirable Substances) and about 40 of these substances fulfil one or more of the criteria (e.g. CMR, EDS) for the REACH Annex XIV candidate list (authorisation). Three substances (phthalates) out of the first and recently published Annex XIV candidate list (in total 15 substances) were found in the Danish printing industry. This paper presents the results of the mapping of chemical candidates and the first results on preparing for actual substitutions.

### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Grafisk Arbejdsgiverforening

Authors: Larsen, H. F. (Intern), Bøgg, C. (Ekstern)

Keywords: (REACH, Printing industry, substitution, chemicals, database)

Number of pages: 486

Pages: 486-487

Publication date: 2009

### Host publication information

Title of host publication: SETAC-Europe: 19th annual meeting, 31 May – 4 June 2009 in Göteborg, Sweden : Extended abstracts

Place of publication: Brussels, Belgium

Publisher: Society of Environmental Toxicology and Chemistry

Main Research Area: Technical/natural sciences

Conference: 19th Annual meeting of Society of Environmental Toxicology and Chemistry, Göteborg, Sweden, 31/05/2009 - 31/05/2009

Source: orbit

Source-ID: 244444

Publication: Research › Article in proceedings – Annual report year: 2009

### **International consensus model for comparative assessment of chemical emissions in LCA**

Under the UNEP-SETAC Life Cycle Initiative the six most commonly used characterisation models for toxic impacts from chemicals were compared and harmonised through a sequence of workshops removing differences which were unintentional or unnecessary. A parsimonious (as simple as possible but as complex as needed) and transparent consensus model, USEtox, was created producing characterisation factors that fall within the range of factors from the harmonised existing characterisation models. The USEtox model together with factors for several thousand substances are currently under review to form the basis of the recommendations from the UNEP-SETAC Life Cycle Initiative in this field.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, European Institute for Energy Research, Radboud Universiteit, University of Michigan, Swiss Federal Institute of Technology, École Polytechnique de Montréal, University of California at Berkeley, Rovira i Virgili University

Authors: Hauschild, M. Z. (Intern), Bachmann, T. M. (Ekstern), Huijbregts, M. A. (Ekstern), Jolliet, O. (Ekstern), Köhler, A. (Ekstern), Larsen, H. F. (Intern), Margni, M. (Ekstern), McKone, T. (Ekstern), MacLeod, M. (Ekstern), van de Meent, D. (Ekstern), Schuhmacher, M. (Ekstern), Rosenbaum, R. K. (Intern)

Pages: 291-296

Publication date: 2008

#### **Host publication information**

Title of host publication: LCE 2008: 15th CIRP International Conference on Life Cycle Engineering: Conference Proceedings : CIRP International Conference on Life Cycle Engineering (15th : 2008 : Sydney, N.S.W.)

Main Research Area: Technical/natural sciences

Conference: 15th CIRP Life Cycle Engineering Conference in Sidney 17-19 March 2008, Sidney, Australia, 01/01/2008

Source: orbit

Source-ID: 264163

Publication: Research › Conference abstract in proceedings – Annual report year: 2008

### **Milestone 4.1 • First draft on complemented LCA methodology**

As described in deliverable 4.1, D4.1 (Larsen et al. 2007) NEPTUNE is using two main types of life cycle impact assessment (LCIA) methodologies when doing LCA studies on the waste water treatment technologies included. The basic methodology is the well known existing EDIP97 methodology (Wenzel et al. 1997, Hauschild and Wenzel 1998) for which the impact assessment on toxicity is PNEC based. However, in order to include the newest development on especially best available practice as regards ecotoxicity a new revised and updated EDIP 200X LCIA methodology has been developed. A first draft of this methodology is presented here. Special issues of waste water have been addressed by including novel development on LCIA methodology for possible impact from pathogens and whole effluent toxicity. Special focus is also allocated to micropollutants with specific toxic mode of action (i.e. endocrine disruptors) and the possibilities and relevance of including impact categories on land use and site-specific assessments have been addressed. Further, the special problems on how to deal with land fill and how to do normalisation and especially weighting of impact potentials are also dealt with. This report is a first draft and in principle only outlines the different issues but is more or less detailed in many cases.

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Olsen, S. I. (Intern), Hauschild, M. Z. (Intern)

Keywords: (LCA, NEPTUNE, LCIA methodology, Waste water, EDIP200X)

Number of pages: 40

Publication date: 2008

#### **Publication information**

Publisher: DTU MAN (EU FP6 project)

Original language: English

Series: Milestone

Number: M4.1

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 231979

Publication: Research › Report – Annual report year: 2008

### **REACH-related substitution within the Danish printing industry**

The accomplishment of the EU REACH regulation will most probably promote substitution within sectors handling a lot of different chemicals like the printing industry. With the aim of being at the cutting edge of this development the Danish EPA together with the Danish printing industry and IPU are running a substitution project. A major part of the work has been

mapping the presence of chemicals which are potential candidates for substitution (e.g. PBT, CMR, vPvB, EDS) within the Danish printing industry. The mapping comprises a combination of a literature study and an investigation of the actual (2007) presence of candidate substances at 15 Danish printing houses including the examination of more than 1000 MSDS's (i.e. products). About 90 of the mapped substances are candidates for substitution according to Danish legislation (List of Undesirable Substances) and more than 20 of these substances fulfil one or more of the criteria (e.g. CMR, EDS) for the REACH Annex XIV candidate list (authorisation). The paper presents the results of the mapping of chemical candidates and the first results of the actual substitutions. Keywords: REACH, chemicals, substitution, printing industry.

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Larsen, H. F. (Intern), Bøgg, C. (Ekstern), Markussen, H. (Ekstern)

Keywords: (Chemicals, Substitution, REACH, Printing industry)

Publication date: 2008

Event: Poster session presented at SETAC Europe 18th Annual Meeting, Warsaw, Poland.

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 231994

Publication: Research › Poster – Annual report year: 2008

#### **REVIEW OF EXISTING LCA STUDIES ON WASTE WATER TREATMENT TECHNOLOGIES**

The EU research project "NEPTUNE" is related to the EU Water Framework Directive and focused on the development of new waste water treatment technologies (WWTT) for municipal waste water. The sustainability of these WWTTs is going to be assessed by the use of life cycle assessment (LCA). New life cycle impact assessment methods on pathogens, whole effluent toxicity and micropollutants will be developed within the project. As part of this work a review of more than 20 previous LCA studies on WWTTs has been done and the findings are summarised on this poster. The review is focused on the relative importance of the different life cycle stages and the individual impact categories in the total impact from the waste water treatment, and the degree to which micropollutants, pathogens and whole effluent toxicity have been included in earlier studies. The results show that more than 30 different WWTT (and even more treatment trains/scenarios) have already been the subject of more or less detailed LCAs. All life cycle stages may be important and all impact categories (except stratospheric ozone depletion) typically included in LCAs may show significance depending on the actual scenario. Potential impacts of pathogens and whole effluent toxicity have not been included in any study, and only a few studies have included micropollutants (in total less than 20 different micropollutants).

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Keywords: (LCA, Review, LCIA, Waste water treatment technologies)

Publication date: 2008

Event: Poster session presented at SETAC Europe 18th Annual Meeting, Warsaw, Poland.

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 231987

Publication: Research › Poster – Annual report year: 2008

#### **Sustainability assessment of advanced wastewater treatment technologies**

As a consequence of the EU Water Framework Directive more focus is now on discharges of hazardous substances from wastewater treatment plants and sewers. Thus, many municipalities in Denmark may have to adopt to future advanced treatment technologies. This paper describes a holistic assessment, which includes technical, economical and environmental aspects. The technical and economical assessment is performed on 5 advanced treatment technologies: sand filtration, ozone treatment, UV exclusively for disinfection of pathogenic microorganisms, membrane bioreactor (MBR) and UV in combination with advanced oxidation. The technical assessment is based on 12 hazardous substances comprising heavy metals, organic pollutants, endocrine disruptors as well as pathogenic microorganisms. The environmental assessment is performed by life cycle assessment (LCA) comprising 9 of the specific hazardous substances and three advanced treatment methods; sand filtration, ozone treatment and MBR. The technical and economic assessment showed that UV solely for disinfection purposes or ozone treatment is the most advantageous advanced treatment methods if the demands are restricted to pathogenic microorganisms. In terms of sustainability, sand filtration is the most advantageous method based on the technical and environmental assessment due to the low energy consumption and high efficiency with regards to removal of heavy metals. Key words | advanced wastewater treatment, life cycle assessment, MBR, ozone treatment, sand filtration, UV treatment.

#### **General information**

State: Published



Organisations: Department of Management Engineering, Innovation and Sustainability, Department of Environmental Engineering

Authors: Høiby, L. (Ekstern), Clauson-Kaas, J. (Ekstern), Wenzel, H. (Ekstern), Larsen, H. F. (Intern), Jacobsen, B. N. (Ekstern), Dalgaard, O. (Ekstern)

Keywords: (UV treatment, Ozone treatment, Advanced wastewater treatment, Life cycle assessment, MBR, Sand filtration )

Pages: 963-968

Publication date: 2008

Main Research Area: Technical/natural sciences

### Publication information

Journal: Water Science and Technology

Volume: 58

Issue number: 5

ISSN (Print): 0273-1223

Ratings:

BFI (2015): BFI-level 1

Scopus rating (2015): 0.469 0.552

BFI (2014): BFI-level 1

Scopus rating (2014): 0.6 0.678

BFI (2013): BFI-level 1

Scopus rating (2013): 0.563 0.698

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 1

Scopus rating (2012): 0.589 0.666

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 1

Scopus rating (2011): 0.608 0.648

ISI indexed (2011): ISI indexed yes

BFI (2010): BFI-level 1

Scopus rating (2010): 0.547 0.605

BFI (2009): BFI-level 1

Scopus rating (2009): 0.593 0.646

BFI (2008): BFI-level 2

Scopus rating (2008): 0.585 0.696

Scopus rating (2007): 0.755 0.781

Scopus rating (2006): 0.704 0.793

Scopus rating (2005): 0.774 0.86

Scopus rating (2004): 0.885 0.917

Scopus rating (2003): 0.88 0.898

Scopus rating (2002): 0.903 0.885

Scopus rating (2001): 0.758 0.968

Scopus rating (2000): 0.765 0.895

Scopus rating (1999): 0.882 0.939

Original language: English

DOIs:

10.2166/wst.2008.450

Source: orbit

Source-ID: 231969

Publication: Research - peer-review › Journal article – Annual report year: 2008

### Sustainable treatment of municipal waste water

The main goal of the EU FP6 NEPTUNE program is to develop new and improve existing waste water treatment technologies (WWTT) and sludge handling technologies for municipal waste water, in accordance with the concepts behind the EU Water Framework Directive. As part of this work, the project will develop and implement a methodology to compare and prioritize these technologies and optimizations based on a holistic approach. This will be achieved through the use of life cycle assessment (LCA) along with cost/efficiency analysis with focus on the effects of nutrients, pathogens and micropollutants (i.e. heavy metals, pharmaceuticals and endocrine disruptors) in the waste water. As a novel approach, the potential ecotoxicity and human toxicity impacts from a high number of micropollutants and the potential

impacts from pathogens will be included. In total, more than 20 different waste water and sludge treatment technologies are to be assessed. This paper will present the first LCA results from running existing life cycle impact assessment (LCIA) methodology on some of the waste water treatment technologies. Keywords: Sustainability, LCA, micropollutants, waste water treatment technologies.

#### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Innovation and Sustainability

Authors: Hansen, P. A. (Intern), Larsen, H. F. (Intern)

Keywords: (LCA, Micropollutants, Sustainability, Waste water treatment technologies)

Publication date: 2008

Event: Poster session presented at SETAC Europe 18th Annual Meeting, Warsaw, Poland.

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 231988

Publication: Research > Poster – Annual report year: 2008

#### USEtox - The UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment

Background, Aim and Scope. In 2005 a comprehensive comparison of LCIA toxicity characterisation models was initiated by the UNEP-SETAC Life Cycle Initiative, directly involving the model developers of CalTOX, IMPACT 2002, USES-LCA, BETR, EDIP, WATSON, and EcoSense. In this paper we describe this model-comparison process and its results—in particular the scientific consensus model developed by the model developers. The main objectives of this effort were (i) to identify specific sources of differences between the models' results and structure, (ii) to detect the indispensable model components, and (iii) to build a scientific consensus model from them, representing recommended practice. Methods. A chemical test set of 45 organics covering a wide range of property combinations was selected for this purpose. All models used this set. In three workshops, the model comparison participants identified key fate, exposure and effect issues via comparison of the final characterisation factors and selected intermediate outputs for fate, human exposure and toxic effects for the test set applied to all models. Results. Through this process, we were able to reduce inter-model variation from an initial range of up to 13 orders of magnitude down to no more than 2 orders of magnitude for any substance. This led to the development of USEtox, a scientific consensus model that contains only the most influential model elements. These were, for example, process formulations accounting for intermittent rain, defining a closed or open system environment, or nesting an urban box in a continental box. Discussion. The precision of the new characterisation factors (CFs) is within a factor of 100-1000 for human health and 10-100 for freshwater ecotoxicity of all other models compared to 12 orders of magnitude variation between the CFs of each model respectively. The achieved reduction of inter-model variability by up to 11 orders of magnitude is a significant improvement. Conclusions. USEtox provides a parsimonious and transparent tool for human health and ecosystem CF estimates. Based on a referenced database, it has now been used to calculate CFs for several thousand substances and forms the basis of the recommendations from UNEP-SETAC's Life Cycle Initiative regarding characterization of toxic impacts in Life Cycle Assessment. Recommendations and Perspectives. We provide both recommended and interim (not recommended and to be used with caution) characterisation factors for human health and freshwater ecotoxicity impacts. After a process of consensus building among stakeholders on a broad scale as well as several improvements regarding a wider and easier applicability of the model, USEtox will become available to practitioners for the calculation of further CFs.

#### General information

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Rosenbaum, R. K. (Intern), Bachmann, T. M. (Ekstern), Gold, L. S. (Ekstern), Huijbregts, M. A. (Ekstern), Jolliet, O. (Ekstern), Juraske, R. (Ekstern), Köhler, A. (Ekstern), Larsen, H. F. (Intern), MacLeod, M. (Ekstern), Margni, M. (Ekstern), McKone, T. E. (Ekstern), Payet, J. (Ekstern), Schuhmacher, M. (Ekstern), van de Meent, D. (Ekstern), Hauschild, M. Z. (Intern)

Keywords: ()

Pages: 532-546

Publication date: 2008

Main Research Area: Technical/natural sciences

#### Publication information

Journal: International Journal of Life Cycle Assessment

Volume: 13

Issue number: 7

ISSN (Print): 0948-3349

Ratings:

BFI (2015): BFI-level 2

Scopus rating (2015): 1.58 1.453

BFI (2014): BFI-level 2  
Scopus rating (2014): 1.799 1.743  
BFI (2013): BFI-level 2  
Scopus rating (2013): 1.701 1.983  
ISI indexed (2013): ISI indexed yes  
BFI (2012): BFI-level 2  
Scopus rating (2012): 1.528 1.72  
ISI indexed (2012): ISI indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): 1.605 1.729  
ISI indexed (2011): ISI indexed yes  
BFI (2010): BFI-level 2  
Scopus rating (2010): 1.471 1.884  
BFI (2009): BFI-level 2  
Scopus rating (2009): 1.228 1.557  
BFI (2008): BFI-level 2  
Scopus rating (2008): 0.892 1.338  
Scopus rating (2007): 0.803 1.237  
Scopus rating (2006): 0.63 1.382  
Scopus rating (2005): 0.646 1.755  
Scopus rating (2004): 0.641 1.488  
Scopus rating (2003): 0.502 1.803  
Scopus rating (2002): 0.295 0.98  
Scopus rating (2001): 0.492 1.648  
Scopus rating (2000): 1.12 2.308  
Scopus rating (1999): 0.429 1.408  
Original language: English  
DOIs:  
10.1007/s11367-008-0038-4  
Source: orbit  
Source-ID: 240962  
Publication: Research - peer-review › Journal article – Annual report year: 2008

### **Weighing environmental advantages and disadvantages of advanced wastewater treatment of micro-pollutants using environmental life cycle assessment**

Much research and development effort is directed towards advances in municipal wastewater treatment aiming at reducing the effluent content of micro-pollutants and pathogens. The objective is to further reduce the eco-toxicity, hormone effects and pathogenic effects of the effluent. Such further polishing of the effluent, however, involves an environmental trade-off: the reduction in eco-toxicity, hormone effects, etc. will happen at the expense of increased resource- and energy consumption. Obviously, at some point of further advances, there must be an 'environmental break-even'. This trade-off was investigated using Life Cycle Assessment (LCA) methodology and based on a literature review of advanced treatment performance. The LCA evaluation comprised sand filtration, ozonation and MBRs and assessed the effect of extending existing tertiary treatment with these technologies on a variety of micro-pollutants being: heavy metals (Cd, Pb, Ni), endocrine disruptors (E2 and EE2), PAH, DEHP, and detergents (LAS & NPE). It was found, in some of the studied scenarios, that more environmental impact may be induced than removed by the advanced treatment. The study showed that for the 3 technologies, sand filtration has the best balance between prevented and induced impacts, and sand filtration proved to have a net environmental benefit under the assumptions used in the study. But the outcome of the study suggests that this is not always the case for ozonation and MBR. Keywords: advanced wastewater treatment; LCA; life cycle assessment; MBR; micro-pollutants; ozonation; sand filtration.

#### **General information**

State: Published

Organisations: Department of Management Engineering, Innovation and Sustainability, Department of Environmental Engineering

Authors: Wenzel, H. (Ekstern), Larsen, H. F. (Intern), Clauson-Kaas, J. (Ekstern), Høiby, L. (Ekstern), Jacobsen, B. N. (Ekstern)

Keywords: (Advanced wastewater treatment, Life cycle assessment, LCA, MBR, Micropollutants, Sand filtration, Ozonation)

Pages: 27-32

Publication date: 2008  
Main Research Area: Technical/natural sciences

### Publication information

Journal: Water Science and Technology

Volume: 57

Issue number: 1

ISSN (Print): 0273-1223

Ratings:

BFI (2015): BFI-level 1

Scopus rating (2015): 0.469 0.552

BFI (2014): BFI-level 1

Scopus rating (2014): 0.6 0.678

BFI (2013): BFI-level 1

Scopus rating (2013): 0.563 0.698

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 1

Scopus rating (2012): 0.589 0.666

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 1

Scopus rating (2011): 0.608 0.648

ISI indexed (2011): ISI indexed yes

BFI (2010): BFI-level 1

Scopus rating (2010): 0.547 0.605

BFI (2009): BFI-level 1

Scopus rating (2009): 0.593 0.646

BFI (2008): BFI-level 2

Scopus rating (2008): 0.585 0.696

Scopus rating (2007): 0.755 0.781

Scopus rating (2006): 0.704 0.793

Scopus rating (2005): 0.774 0.86

Scopus rating (2004): 0.885 0.917

Scopus rating (2003): 0.88 0.898

Scopus rating (2002): 0.903 0.885

Scopus rating (2001): 0.758 0.968

Scopus rating (2000): 0.765 0.895

Scopus rating (1999): 0.882 0.939

Original language: English

DOIs:

10.2166/wst.2008.819

Source: orbit

Source-ID: 210340

Publication: Research - peer-review › Journal article – Annual report year: 2008

### Database on REACH-related substitution within the Danish printing industry

#### General information

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Larsen, H. F. (Intern), Bøgg, C. (Ekstern), Markussen, H. (Ekstern), Alstrup, L. (Ekstern)

Publication date: 2007

Event: Poster session presented at SETAC Europe 17th Annual Meeting : Multiple stressors for the environment and human health - present and future challenges and perspectives, Porto, Portugal, 20-24 May, .

Main Research Area: Technical/natural sciences

Publication: Research › Poster – Annual report year: 2007

#### **Deliverable 4.1 Homogeneous LCA methodology agreed by NEPTUNE and INNOWATECH**

In order to do a life cycle assessment (LCA) of a waste water treatment technique, a system to handle the mapped inventory data and a life cycle impact assessment (LCIA) method/model is needed. Besides NEPTUNE, another EU-funded project has the same methodology need namely INNOWATECH (contract No. 036882) running in parallel with NEPTUNE but focusing on industrial waste water. With the aim of facilitating cooperation between the two projects a common LCA methodology framework has been worked out and is described in the following. This methodology work has been done as a joint effort between NEPTUNE WP4 and INNOWATECH WP4 represented by the WP4 lead partner IVL. The aim of the co-operation is to establish common methodologies and/or LCA models and/or tools in order to achieve a homogenous approach in INNOWATECH and NEPTUNE. Further, the aim is to facilitate possibilities of data exchange between the two projects and eventually normalise the final output. A coordination/working group with representatives from INNOWATECH (WP4) and NEPTUNE (WP4) has been set up. It consists of the following representatives from the two projects: NEPTUNE: Henrik Fred Larsen (DTU/IPU), Michael Hauschild (DTU), Henrik Wenzel (SDU). INNOWATECH: Mats Almemark (IVL), Christian Junestedt (IVL). In support of this work and as a starting point for especially NEPTUNE WP4, a review of existing LCA studies on waste water treatment technologies has been done by DTU and is included as an Appendix.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Swedish Environmental Research Institute

Authors: Larsen, H. F. (Intern), Hauschild, M. Z. (Intern), Wenzel, H. (Intern), Almemark, M. (Ekstern)

Keywords: (LCA, EDIP, Micropollutants, Waste water)

Number of pages: 34

Publication date: 2007

#### **Publication information**

Original language: English

Series: EU FP6 project, deliverable

Number: 4.1

Main Research Area: Technical/natural sciences

Electronic versions:

D4.1.pdf

Links:

[http://www.eu-neptune.org/Publications%20and%20Presentations/index\\_EN](http://www.eu-neptune.org/Publications%20and%20Presentations/index_EN)

Source: orbit

Source-ID: 267056

Publication: Research › Report – Annual report year: 2007

**Erratum: Evaluation of Ecotoxicity Effect Indicators for Use in LCIA: Eq. 8 was lacking on p. 32, No. 1, Vol. 12, 2007**

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Pages: 92

Publication date: 2007

Main Research Area: Technical/natural sciences

#### **Publication information**

Journal: International Journal of Life Cycle Assessment

Volume: 12

Issue number: 2

ISSN (Print): 0948-3349

Ratings:

BFI (2015): BFI-level 2

Scopus rating (2015): 1.58 1.453

BFI (2014): BFI-level 2

Scopus rating (2014): 1.799 1.743

BFI (2013): BFI-level 2

Scopus rating (2013): 1.701 1.983

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 2

Scopus rating (2012): 1.528 1.72  
ISI indexed (2012): ISI indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): 1.605 1.729  
ISI indexed (2011): ISI indexed yes  
BFI (2010): BFI-level 2  
Scopus rating (2010): 1.471 1.884  
BFI (2009): BFI-level 2  
Scopus rating (2009): 1.228 1.557  
BFI (2008): BFI-level 2  
Scopus rating (2008): 0.892 1.338  
Scopus rating (2007): 0.803 1.237  
Scopus rating (2006): 0.63 1.382  
Scopus rating (2005): 0.646 1.755  
Scopus rating (2004): 0.641 1.488  
Scopus rating (2003): 0.502 1.803  
Scopus rating (2002): 0.295 0.98  
Scopus rating (2001): 0.492 1.648  
Scopus rating (2000): 1.12 2.308  
Scopus rating (1999): 0.429 1.408  
Original language: English

#### **Bibliographical note**

Erratum

Source: orbit

Source-ID: 210343

Publication: Research - peer-review › Journal article – Annual report year: 2006

#### **Evaluation of Ecotoxicity Effect Indicators for Use in LCIA**

Goal, Scope and Background. The paper describes different ecotoxicity effect indicator methods/approaches. The approaches cover three main groups, viz. PNEC approaches, PAF approaches and damage approaches. Ecotoxicity effect indicators used in life cycle impact assessment (LCIA) are typically modelled to the level of impact, indicating the potential impact on 'ecosystem health'. The few existing indicators, which are modelled all the way to damage, are poorly developed, and even though relevant alternatives from risk assessment exist (e.g. recovery time and mean extinction time), these are unfortunately at a very early stage of development, and only few attempts have been made to include them in LCIA. Methods. The approaches are described and evaluated against a set of assessment criteria comprising compatibility with the methodological requirements of LCIA, environmental relevance, reproducibility, data demand, data availability, quantification of uncertainty, transparency and spatial differentiation. Results and Discussion. The results of the evaluation of the two impact approaches (i.e. PNEC and PAF) show both pros and cons for each of them. The assessment factor-based PNEC approach has a low data demand and uses only the lowest data (e.g. lowest NOEC value). Because it is developed in tiered risk assessment, and hence makes use of conservative assessment factors, it is not optimal, in its present form, to use in the comparative framework of LCIA, where best estimates are sought. The PAF approaches have a higher data demand but use all data and can be based on effect data (PNEC is no-effect-based), thus making these approaches non-conservative and more suitable for LCIA. However, indiscriminate use of ecotoxicity data tends to make the PAF-approaches no more environmentally relevant than the assessment factor-based PNEC approaches. The PAF approaches, however, can at least in theory be linked to damage modelling. All the approaches for damage modelling which are included here have a high environmental relevance but very low data availability, apart from the 'media recovery- approach', which depends directly on the fate model. They are all at a very early stage of development. Conclusion, Recommendations and Outlook. An analysis of the different PAF approaches shows that the crucial point is according to which principles and based on which data the hazardous concentration to 50% of the included species (i.e. HC50) is estimated. The ability to calculate many characterisation factors for ecotoxicity is important for this impact category to be included in LCIA in a proper way. However, the access to effect data for the relevant chemicals is typically limited. So, besides the coupling to damage modelling, the main challenge within the further development and improvement of ecotoxicity effect indicators is to find an optimal method to estimate HC50 based on little data.

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Keywords: (ecotoxicity effect indicators, Damage approaches, hazardous)

Pages: 24-33

Publication date: 2007

Main Research Area: Technical/natural sciences

### Publication information

Journal: International Journal of Life Cycle Assessment

Volume: 12

Issue number: 1

ISSN (Print): 0948-3349

Ratings:

BFI (2015): BFI-level 2

Scopus rating (2015): 1.58 1.453

BFI (2014): BFI-level 2

Scopus rating (2014): 1.799 1.743

BFI (2013): BFI-level 2

Scopus rating (2013): 1.701 1.983

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 2

Scopus rating (2012): 1.528 1.72

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 2

Scopus rating (2011): 1.605 1.729

ISI indexed (2011): ISI indexed yes

BFI (2010): BFI-level 2

Scopus rating (2010): 1.471 1.884

BFI (2009): BFI-level 2

Scopus rating (2009): 1.228 1.557

BFI (2008): BFI-level 2

Scopus rating (2008): 0.892 1.338

Scopus rating (2007): 0.803 1.237

Scopus rating (2006): 0.63 1.382

Scopus rating (2005): 0.646 1.755

Scopus rating (2004): 0.641 1.488

Scopus rating (2003): 0.502 1.803

Scopus rating (2002): 0.295 0.98

Scopus rating (2001): 0.492 1.648

Scopus rating (2000): 1.12 2.308

Scopus rating (1999): 0.429 1.408

Original language: English

DOIs:

10.1065/lca2006.12.287

Source: orbit

Source-ID: 195716

Publication: Research - peer-review › Journal article – Annual report year: 2007

### GM-troph – a low data demand ecotoxicity effect indicator for use in LCIA

#### General information

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hauschild, M. Z. (Intern)

Pages: 79-91

Publication date: 2007

Main Research Area: Technical/natural sciences

#### Publication information

Journal: International Journal of Life Cycle Assessment

Volume: 12

Issue number: 2

ISSN (Print): 0948-3349

Ratings:

BFI (2015): BFI-level 2

Scopus rating (2015): 1.58 1.453

BFI (2014): BFI-level 2

Scopus rating (2014): 1.799 1.743

BFI (2013): BFI-level 2

Scopus rating (2013): 1.701 1.983

ISI indexed (2013): ISI indexed yes

BFI (2012): BFI-level 2

Scopus rating (2012): 1.528 1.72

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 2

Scopus rating (2011): 1.605 1.729

ISI indexed (2011): ISI indexed yes

BFI (2010): BFI-level 2

Scopus rating (2010): 1.471 1.884

BFI (2009): BFI-level 2

Scopus rating (2009): 1.228 1.557

BFI (2008): BFI-level 2

Scopus rating (2008): 0.892 1.338

Scopus rating (2007): 0.803 1.237

Scopus rating (2006): 0.63 1.382

Scopus rating (2005): 0.646 1.755

Scopus rating (2004): 0.641 1.488

Scopus rating (2003): 0.502 1.803

Scopus rating (2002): 0.295 0.98

Scopus rating (2001): 0.492 1.648

Scopus rating (2000): 1.12 2.308

Scopus rating (1999): 0.429 1.408

Original language: English

DOIs:

10.1065/lca2006.12.288

Source: orbit

Source-ID: 201629

Publication: Research - peer-review › Journal article – Annual report year: 2007

## **International consensus model for comparative assessment of chemicals**

### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Hauschild, M. Z. (Intern), Bachmann, T. (Ekstern), Huijbregts, M. (Ekstern), Jolliet, O. (Ekstern), Koehler, A. (Ekstern), Larsen, H. F. (Intern), Margni, M. (Ekstern), McKone, T. (Ekstern), McLeod, M. (Ekstern), van de Meent, D. (Ekstern), Schuhmacher, M. (Ekstern), Rosenbaum, R. K. (Intern)

Publication date: 2007

Event: Poster session presented at SETAC Europe 17th Annual Meeting : Multiple stressors for the environment and human health - present and future challenges and perspectives, Porto, Portugal, 20-24 May, .

Main Research Area: Technical/natural sciences

Publication: Research › Poster – Annual report year: 2007

## **New methodology in life cycle impact assessment (LCIA) of waste water treatment**

### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Wenzel, H. (Intern), Hauschild, M. Z. (Intern)

Publication date: 2007

Event: Poster session presented at SETAC Europe 17th Annual Meeting : Multiple stressors for the environment and human health - present and future challenges and perspectives, Porto, Portugal, 20-24 May, .



Main Research Area: Technical/natural sciences  
Publication: Research › Poster – Annual report year: 2007

### **New methodology in life cycle impact assessment (LCIA) of waste water treatment**

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Wenzel, H. (Intern), Hauschild, M. Z. (Intern)

Publication date: 2007

Event: Poster session presented at 5th IWA Specialised Conference on Assessment & Control of Micropollutants / Hazardous Substances in Water, Frankfurt am Main, Germany.

Main Research Area: Technical/natural sciences

Publication: Research › Poster – Annual report year: 2007

### **The UNEP/SETAC recommended characterisation factors for human health and aquatic ecotoxicity: results and future**

Over the last two years, the developers of seven toxicity characterization models collaborated to carry out a comprehensive model comparison as part of the UNEP/SETAC Life Cycle Initiative. The models in this evaluation included CalTOX, IMPACT 2002, USES-LCA, BETR, EDIP, WATSON, and EcoSense. This paper summarizes and draws lessons from this model evaluation process. The main objectives of this effort were to 1) identify specific sources of differences in model results, 2) define common and indispensable model components, and 3) use the selected models to build a “scientific consensus” model, called USEtox, to serve as a repository for recommended practice. USEtox is a parsimonious and transparent tool that currently provides human-health characterisation factors (CFs) for some 1000 chemicals and aquatic ecotoxicity CFs for more than 2000 substances. The accuracy of these factors relative to other models remains within 1-3 orders of magnitude compared to 12 orders of magnitude variation among the chemicals. The main task of model development is complete, but the following future activities are foreseen for the upcoming second phase of the UNEP/SETAC Life Cycle Initiative: 1) increase of substance coverage and quality assurance of substance data; 2) accommodation of metals; 3) inclusion of terrestrial and marine ecotoxicity; 4) incorporation of indoor emissions; 5) including parameter uncertainty in the uncertainty estimates on the CFs; 6) publication of model documentation 7) development and distribution of a user-friendly version of USEtox; 8) industry/stakeholder workshops on comparative assessment of chemicals and training courses in USEtox. The promising scientific results now need to be transferred into daily LCA practice, which is the main goal of these activities, aiming at a broad acceptance and consideration of the toxicity impact categories.

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, École Polytechnique de Montréal, European Institute for Energy Research, Radboud Universiteit, University of Michigan, University of California at Berkeley, Rovira i Virgili University, Swiss Federal Institute of Technology

Authors: Rosenbaum, R. K. (Ekstern), Hauschild, M. Z. (Intern), Bachmann, T. M. (Ekstern), Huijbregts, M. A. (Ekstern), Jolliet, O. (Ekstern), Larsen, H. F. (Intern), Margni, M. (Ekstern), McKone, T. (Ekstern), van de Meent, D. (Ekstern), Schuhmacher, M. (Ekstern), Köhler, A. (Ekstern), MacLeod, M. (Ekstern)

Number of pages: 334

Publication date: 2007

Event: Poster session presented at 28th annual meeting of SETAC North America, Milwaukee, 11-15 November 2007, Milwaukee, Wisconsin, United States of America, .

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 264508

Publication: Research › Poster – Annual report year: 2007

### **Towards a consensus model in chemical characterisation modelling for LCA: comparison and harmonisation of models for fate and ecotoxicity effects**

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: van de Meent, D. (Ekstern), Bachmann, T. (Ekstern), Hauschild, M. Z. (Intern), Huijbregts, M. (Ekstern), Jolliet, O. (Ekstern), Koehler, A. (Ekstern), Larsen, H. F. (Intern), Margni, M. (Ekstern), McKone, T. (Ekstern), McLeod, M. (Ekstern), Rosenbaum, R. K. (Intern), Schuhmacher, M. (Ekstern)

Publication date: 2007

Event: Poster session presented at SETAC Europe 17th Annual Meeting : Multiple stressors for the environment and human health - present and future challenges and perspectives, Porto, Portugal, 20-24 May, .

Main Research Area: Technical/natural sciences

Publication: Research › Poster – Annual report year: 2007

### **Towards a consensus model in chemical characterisation modelling for LCA: comparison and harmonisation of models for human exposure and toxicity**

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Rosenbaum, R. K. (Intern), Hauschild, M. Z. (Intern), Jolliet, O. (Ekstern), van de Meent, D. (Ekstern), Huijbregts, M. (Ekstern), Margni, M. (Ekstern), McLeod, M. (Ekstern), Schuhmacher, M. (Ekstern), Larsen, H. F. (Intern), Bachmann, T. (Ekstern), Koehler, A. (Ekstern)

Publication date: 2007

Event: Abstract from SETAC Europe 17th Annual Meeting : Multiple stressors for the environment and human health - present and future challenges and perspectives, Porto, Portugal, 20-24 May, .

Main Research Area: Technical/natural sciences

Publication: Research › Conference abstract for conference – Annual report year: 2007

### **Weighting environmental advantages and disadvantages of advanced waste water treatment of micro-pollutants using environmental life cycle assessment**

#### **General information**

State: Published

Organisations: Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Wenzel, H. (Intern), Larsen, H. F. (Intern), Clausson-Kaas, J. (Ekstern), Høiby, L. (Ekstern), Jacobsen, B. (Ekstern)

Publication date: 2007

Event: Abstract from 5th IWA Specialised Conference on Assessment & Control of Micropollutants / Hazardous Substances in Water, Frankfurt am Main, Germany.

Main Research Area: Technical/natural sciences

Publication: Research › Conference abstract for conference – Annual report year: 2007

### **Ecolabelling of printed matter. Part I**

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering, Institute for Product Development, The graphic association of Denmark

Authors: Johnsen, N. (Ekstern), Bøg, C. (Ekstern), Poll, C. (Intern), Larsen, H. F. (Intern)

Number of pages: 82

Publication date: 2006

#### **Publication information**

Publisher: Ministry for Environment and Energy, Environmental Protection Agency

ISBN (Print): 87-7052-170-0

Original language: English

Series: Environmental Project

Number: 1110

Main Research Area: Technical/natural sciences

Electronic versions:

Ecolabelling\_of\_printed\_matter\_1.pdf

Publication: Research › Report – Annual report year: 2006

### **Ecolabelling of printed matter. Part II: Life cycle assessment of model sheet fed offset printed matter**

#### **General information**

State: Published

Organisations: Quantitative Sustainability Assessment, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Hauschild, M. Z. (Intern), Hansen, M. S. (Intern)

Number of pages: 142

Publication date: 2006

#### **Publication information**

Publisher: Ministry for Environment and Energy, Environmental Protection Agency  
ISBN (Print): 87-7052-174-3  
Original language: English

Series: Working Report

Number: 24

Main Research Area: Technical/natural sciences

Electronic versions:

[Ecolabelling\\_of\\_printed\\_matter\\_2.pdf](#)

Publication: Research > Report – Annual report year: 2006

### **Towards consensus in chemical characterization modeling for LCA: comparison and harmonization of models for human exposure and toxicity**

A comprehensive LCIA characterization model comparison is being undertaken in the UNEP/SETAC Life Cycle Initiative, focusing on toxicity impacts and directly involving the developers of all models included. The main objective is to identify where differences come from, what indispensable model components are and if there can be a consensus model built from them, leading towards recommended practice in chemical characterization for LCIA. The models were selected in an open process inviting all models identified to be capable of characterizing a chemical in terms of environmental fate, human exposure, human toxicity and ecotoxicity. The invitation was accepted by the developers of CalTOX, IMPACT 2002, USES-LCA, EDIP, WATSON, and EcoSense. A consistent chemical test set comprising 66 organic (generic, amphiphilic and dissociating) and inorganic (metals, salts) compounds was selected representing a wide range of substance property combinations. All compared models showed correlation for human health endpoints for generic organics, with high variations on individual chemicals, typically with high Kow. For the other organics and inorganics, less agreement was observed. Influential processes and assumptions were identified and agreed upon to implement in all models for harmonization. These were, e.g., an urban box nested in a continental box with fixed surfaces and populations, consistent biotransfer and –concentration factors from experiments or one source/model, vegetation as an exposure pathway is determined by air-plant and soil-plant BCF correlations. For human toxicity, safety factors are avoided, directly using the TD50 benchmark dose with an applied slope on the dose response curve. Human data are preferred and animal-human extrapolation is done using allometrically based factors. Route-to-route extrapolation options were also explored.

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering, École Polytechnique Fédérale de Lausanne, University of Nijmegen, University of Michigan, École Polytechnique de Montréal, University of California at Berkeley, National Institute for Public Health and Environment, Rovira i Virgili University, Eidgenössische Technische Hochschule

Authors: Rosenbaum, R. (Ekstern), Hauschild, M. Z. (Intern), Bachmann, T. (Ekstern), Huijbregts, M. (Ekstern), Jolliet, O. (Ekstern), Larsen, H. F. (Intern), Margni, M. (Ekstern), McKone, T. (Ekstern), van de Meent, D. (Ekstern), Schuhmacher, M. (Ekstern), Köhler, A. (Ekstern), MacLeod, M. (Ekstern)

Number of pages: 12

Publication date: 2006

#### **Host publication information**

Title of host publication: Global Environment and Sustainability: Sound Science in a world of diversity : Proceedings of the 27th annual meeting of SETAC North America

Main Research Area: Technical/natural sciences

Conference: Global Environment and Sustainability: Sound Science in a world of diversity : 27th annual meeting of SETAC North America, Montreal, Canada, 01/01/2006

Source: orbit

Source-ID: 194291

Publication: Research - peer-review > Conference abstract in proceedings – Annual report year: 2006

### **Towards consensus in comparative chemical characterization modeling for LCIA: Efforts within the UNEP/SETAC Life Cycle Initiative**

The Task Force on Toxic Impacts under the UNEP/SETAC Life Cycle Initiative is developing recommendations on characterization models and characterization factors for human toxicity and ecotoxicity impacts in Life Cycle Impact Assessment (LCIA). Building on experience from earlier model development work within, for instance, the OECD, and guidance from a series of expert workshops held between 2002 and 2005, preliminary guidelines focusing on chemical fate, and human and ecotoxic effects were established. For further elaboration of the fate-, exposure- and effect-sides of the modeling, six models were compared, focusing on their structure and results in terms of characterization factors. Through three workshops, modelers identified crucial fate, exposure and effect issues for which the presently available models differ. Between the workshops, the models were harmonized, removing identified unnecessary differences. Based on the adapted set of models and their outcomes, and on the earlier guidelines for fate modeling, overall guidelines for toxicity modeling in LCIA were developed. In line with these overall guidelines, a simple consensus model was developed. This model is collectively owned by the Task Force and the model providers. While the compared models and their

differences are important tools to further advance LCA science, the consensus model is intended to provide a generally agreed and scientifically sound method to calculate consistent characterization factors for use in LCA practice and to be the basis of the "recommended practice" for calculation of characterization factors for chemicals under authority of the UNEP/SETAC Life Cycle Initiative.

### General information

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering, University of Nijmegen, University of Michigan, École Polytechnique de Montréal, University of California at Berkeley, Eidgenössische Technische Hochschule, Rovira i Virgili University, École Polytechnique Fédérale de Lausanne

Authors: Hauschild, M. Z. (Intern), Bachmann, T. (Ekstern), Huijbregts, M. (Ekstern), Jolliet, O. (Ekstern), Larsen, H. F. (Intern), Margni, M. (Ekstern), McKone, T. (Ekstern), MacLeod, M. (Ekstern), Schuhmacher, M. (Ekstern), Rosenbaum, R. K. (Ekstern)

Number of pages: 262

Publication date: 2006

### Host publication information

Title of host publication: Global Environment and Sustainability: : Sound Science in a world of diversity

Main Research Area: Technical/natural sciences

Conference: Global Environment and Sustainability: : Sound Science in a world of diversity, Montreal, Canada, 01/01/2006

Source: orbit

Source-ID: 194293

Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2006

### Assessment of chemical emissions in life cycle impact assessment - focus on low substance data availability and

Life cycle assessment (LCA) studies on products or services seem generally to be carried out without a proper inclusion of potential toxic impacts from emissions of chemicals. The first goal of the thesis is to investigate this statement and to clarify whether or not the outcome of an LCA can be significantly dependent on the inclusion of toxicity- or chemical-related impact categories. The two main reasons for poor coverage of potential toxic impacts from chemical emissions in LCA studies are lack of available data on upstream emissions (e.g. emissions during production of raw materials) and lack of substance data on known emissions. To be able to characterize the potential toxic impacts on humans and the environment of chemical emissions, substance data on fate and effect are needed. The second goal of this thesis is to investigate how to deal with low substance data availability on especially effect data within the context of LCA, when the aim is to improve the inclusion of toxicity- or chemical-related impact categories. The first goal regarding the significance of potential toxic impacts in LCA is investigated by carrying out a full LCA case study on printed matter and putting special emphasis on the inclusion of chemical emissions. The second goal regarding low data availability is addressed in two ways. First by introducing selection methods, which are chemical screening methods designed to select the most significant chemical emissions on a low to very low data availability. Secondly by developing a low data demand ecotoxicity effect indicator to be used together with a fate indicator, when estimating the potential impact of chemical emissions. The results of the case study document that for LCAs on printed matter, the inclusion of chemical-related impact categories can be decisive for the outcome, and it shows that chemical-related impact categories are poorly or not at all included in previous studies. The share for the total environmental impact of for example the printing process in the case study is reduced from 41% to 10%, if the chemical-related impact categories are excluded. So, the basis for defining for example ecolabelling criteria (typically based on life cycle thinking) on printed matter is substantially different depending on whether or not the chemical-related impact categories are (properly) included. The investigation on selection methods shows that only three chemical screening methods, associated with a characterisation method, and therefore here defined as selection methods, actually exist to day. Selection method performance criteria are developed including demands on consistency in prioritisation with associated characterisation method, applicability to different chemical groups, high data availability combined with low data demand, data useable in characterisation, user friendliness and transparency. A mainly qualitative evaluation of the existing selection methods against these performance criteria shows that none of these score high on all criteria, and this indicates the need for development of new selection methods. Recommendations on which components to include, which issues to address and general principles for developing selection methods are therefore given. A quantitative evaluation of the consistency in chemical ranking between the existing selection methods (EDIP-selection, Priofactor and CPM-selection), the risk ranking method EURAM, and the characterisation methods EDIP97 and CPM, is performed. The result of this evaluation shows a good correlation between the ranking of all the tested methods, but strongest between the EDIP97 method and its two associated selection methods EDIP-selection (revised version) and Priofactor. A statistical test of correlation in ranking between EDIP97, Priofactor, CPM and EURAM shows significant correlation in all cases. The main reason for this result is that a common perception of what makes a substance ecotoxicologically problematic underlies all four methods. Nevertheless, some outliers as compared to the EDIP97 ranking are identified. These outliers are due to specific characteristics of each of the methods which for certain combinations of substance properties may result in false negatives or false positives as compared to EDIP97. These characteristics include the influence of data availability on the size of assessment factors for conversion of acute effect data to chronic values, and whether or not mode of entry is taken into account in the fate modelling. Further, the reversing of the effect of toxicity on ranking by negative logKow values is observed when logKow is a direct factor in the expression, and there is a significant influence of the way in which the BCF is estimated and included. The second part of the second goal of this thesis, which deals with low availability of substance effect data, is addressed by carrying out an inventory of existing ecotoxicity effect indicator approaches, including a qualitative evaluation based on developed

performance criteria. Both impact approaches, and damage approaches, which are all at an early development stage, are included. The evaluation of the existing impact approaches, i.e. the assessment factor-based PNEC approach and the PAF-based approach, shows pros and cons for both. However, taking the comparative nature of LCA and its aim for best estimate into account, and combining this with the possibilities for reducing the data demand of an EC50-based PAF approach, and further including the (at least theoretical) connection to damage approaches, leads to the choice of an effect-based average PAF ecotoxicity effect indicator expressed by  $0.5/HC50EC50$  for further development. The most reasonable way to estimate the hazardous concentration for 50% of the included species (HC50) based on only three acute laboratory effect data is hereafter investigated by testing and discussing different ways of estimating averages (e.g. median and geometric mean), different data selection strategies and different ways of estimating uncertainty (confidence) limits around the HC50EC50 value. The results of this investigation show that the geometric mean is the most robust estimator for small data sets. Seeking the coverage of many chemicals in LCA and considering the fact that the main part of the useable single species laboratory test data (EC50) is on algae, crustacean and fish, which in practice represent the trophic levels primary producers, primary consumers and secondary consumers, the use of a minimum of three acute EC50 values from each of these three trophic levels is recommended when estimating HC50EC50. Due to the comparative nature of LCA, the possible bias from severe unequal species representation and inclusion of erroneous data, due to bad non-standardised test conditions, should be avoided by only including tests on standard organisms fulfilling certain defined test criteria on durations and endpoints. Further, in order to avoid the effect of possible haphazard or regulatory determined species representations in the data set used, which may be decisive for the weighting of each trophic level in the estimation, the geometric mean based on the average of the averages within each trophic level is chosen for the ecotoxicity effect indicator GM-troph. Hereby, it is consciously chosen to put equal weight on each trophic level. The statistical confidence limits around the GM-troph are in most cases too wide, because the average is based on only three data values, making a statistically significant differentiation between the different toxicants nearly impossible. However, test on fictitious three data value test sets based on combinations of max and min values from a larger 'mother' data set indicates that the use of the min and max value among the three data value GM-troph data set (i.e. average within algae, average within crustacean and average within fish) as max-min limits around GM-troph gives a reasonable (and as good as confidence limits) certainty that the 'true' GM-troph value (based on the full 'mother' data set) lies within the interval. The inclusion of the toxicity-related impact categories in LCA at a similar level as the better established impact categories, like global warming, is far from achieved yet. This thesis point at relatively well functioning selection methods and defines the framework including performance criteria and recommendations on how to improve existing selection methods and how to develop new ones. By introducing the GM-troph this thesis contributes with a robust, low data demanding effect part of the ecotoxicity characterisation factor. The GM-troph has the potential of facilitating a high number of characterisation factors which are robust with relatively low uncertainty if combined with a 'fate part' of equal strength. The way for further improvement of the involvement of toxicity-related impact categories in LCA is hereby facilitated.

### General information

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern)

Number of pages: 193

Publication date: 2004

### Publication information

ISBN (Print): 87-91035-22-8

Original language: English

Main Research Area: Technical/natural sciences

Electronic versions:

PhD-thesis-rev.pdf

Source: orbit

Source-ID: 177953

Publication: Research › Ph.D. thesis – Annual report year: 2004

### Ecotoxicity Effect Indicator for use in the OMNIITOX Base Model

The ecotoxicity effect indicator (EFI) is used together with the input results from the fate modelling when calculating characterisation factors for ecotoxicity within life-cycle impact assessment (LCIA). A number of methods have been proposed and used in recent years involving different approaches for the estimation of the EFI. However none of these methods are found to be adequately robust and/or able to work on the low data input defined by the OMNIITOX Base Model (BM), i.e. a minimum of three acute EC50 values. Given the fact that the BM should be applicable to a significant number of chemicals, this requirement follows from the current and the most likely future data availability as defined by the proposed EU chemicals policy REACH. In this paper, a theoretical elaboration of effect-based average approaches (arithmetic mean, geometric mean and median) and the non-effect based approach (PNEC) is made focusing on their statistical robustness. Considerations about the possibility to relate the effect indicator to damage on the endpoint, the ecosystem, are also included. The effect-based approaches are tested for their robustness in estimating an HC50 in a practical test on datasets from eleven different substances representing seven different toxic modes of action (TMoA). On the basis of the theoretical elaboration and the practical tests it is recommended for the EFI to use the GM-trophic calculated as the geometric mean of three EC50 values, one from each of the three trophic levels, primary producers,

primary consumers and secondary consumers comprising three different taxa, i.e. algae, crustacean (invertebrates) and fish. If more than three useable EC50 are available then the geometric means within each trophic level are used as input data to the final calculation.

#### General information

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering, Quantitative Sustainability Assessment

Authors: Larsen, H. F. (Intern), Payet, J. (Ekstern), Molander, S. (Ekstern), Hauschild, M. Z. (Intern)

Publication date: 2004

#### Host publication information

Title of host publication: 14th annual meeting of SETAC Europe

Place of publication: Brussels

Publisher: Society of Environmental Toxicology and Chemistry

Main Research Area: Technical/natural sciences

Conference: SETAC Europe 14th annual meeting, Prague, Czech Republic, 18/04/2004 - 18/04/2004

Source: orbit

Source-ID: 177951

Publication: Research > Article in proceedings – Annual report year: 2004

#### Evaluation of selection methods for toxicological impacts in LCA. Recommendations for OMNIITOX.

Goal, Scope and Background. The aim of this study has been to come up with recommendations on how to develop a selection method (SM) within the method development research of the OMNIITOX project. An SM is a method for prioritization of chemical emissions to be included in a Life Cycle Impact Assessment (LCIA) characterisation, in particular for (eco)toxicological impacts. It is therefore designed for pre-screening to support a characterisation method. The main reason why SMs are needed in the context of LCIA is the high number of chemical emissions that potentially contribute to the impacts on ecosystems and human health. It will often not be feasible to cover all emissions with characterisation factors and therefore there exists a real need to focus the effort on the most significant chemical emissions in the characterisation step. Until now not all LCA studies include toxicity related impact categories, and when they do there are typically many gaps. This study covers the only existing methods explicitly designed as SMs (EDIP-selection, Priofactor and CPM-selection), the dominating Chemical Ranking and Scoring (CRS) method in Europe (EURAM) and in USA (WMPT) that can be adapted for this purpose, as well as methods presenting novel approaches which could be valuable in the development of improved SMs (CART analysis and Hasse diagramme). Methods. The included methods are described. General guidance principles established for CRS systems are applied to SMs and a set of criteria for good performance of SMs is developed. The included methods are finally evaluated against these criteria. Results and Discussion. Two of the most important performance criteria include providing consistent results relative to the more detailed, associated characterisation methods and the degree of data availability to ensure broader chemical coverage. Applicability to different chemical groups, user friendliness, and transparency are also listed amongst the important criteria. None of the evaluated methods currently fulfil all of the proposed criteria to a degree that excludes the need for development of improved selection methods. Conclusion and Recommendations. For the development of SMs it is recommended that the general principles for CRS systems as applied to SMs are taken into account. Furthermore, special attention should be paid to some specific issues, i.e. the emitted amount should be included, data availability should enable broad chemical coverage, and when identifying priority chemicals for the characterisation, the developed SM should generate few false positives (chemical emissions classified wrongly as being of high concern) and no (significant) false negatives (classified wrongly as being of low concern) as compared to the associated characterisation method. These recommendations are not only relevant for a stand alone SM, but also valuable when dealing with simple characterisation methods associated with a higher tier characterisation method. Outlook. There are several questions that need to be answered before an optimal SM can be developed, inter alia: Is it optimal to use simple measured data with high availability or are QSAR estimates of more complex and relevant data better? Which key parameters to include and how? Is a statistical approach, like linear regression of characterisation factors or CART analysis, the best solution?

#### General information

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Birkved, M. (Intern), Hauschild, M. Z. (Intern), Pennington, D. W. (Ekstern), Guinée, J. B. (Ekstern)

Keywords: (Simple characterisations methods, Toxicity related impact categories, Life cycle impact assessment, Evaluation criteria, Chemical Ranking and Scoring (CRS), Selection methods)

Pages: 307-319

Publication date: 2004

Main Research Area: Technical/natural sciences

#### Publication information

Journal: International Journal of Life Cycle Assessment

Volume: 9

Issue number: 5  
ISSN (Print): 0948-3349  
Ratings:

BFI (2015): BFI-level 2  
Scopus rating (2015): 1.58 1.453  
BFI (2014): BFI-level 2  
Scopus rating (2014): 1.799 1.743  
BFI (2013): BFI-level 2  
Scopus rating (2013): 1.701 1.983  
ISI indexed (2013): ISI indexed yes  
BFI (2012): BFI-level 2  
Scopus rating (2012): 1.528 1.72  
ISI indexed (2012): ISI indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): 1.605 1.729  
ISI indexed (2011): ISI indexed yes  
BFI (2010): BFI-level 2  
Scopus rating (2010): 1.471 1.884  
BFI (2009): BFI-level 2  
Scopus rating (2009): 1.228 1.557  
BFI (2008): BFI-level 2  
Scopus rating (2008): 0.892 1.338  
Scopus rating (2007): 0.803 1.237  
Scopus rating (2006): 0.63 1.382  
Scopus rating (2005): 0.646 1.755  
Scopus rating (2004): 0.641 1.488  
Scopus rating (2003): 0.502 1.803  
Scopus rating (2002): 0.295 0.98  
Scopus rating (2001): 0.492 1.648  
Scopus rating (2000): 1.12 2.308  
Scopus rating (1999): 0.429 1.408

Original language: English

DOIs:

10.1007/BF02979420

Source: orbit

Source-ID: 63566

Publication: Research - peer-review › Journal article – Annual report year: 2003

### **Implementation of the ecotoxicological, effects module**

The goal of this report is to come up with recommendations on how to calculate the ecotoxicity effect indicator (termed ecotox effect indicator) for use in the OMNIITOX base model (BM). The ecotox effect indicator is used together with the input from the fate modelling to calculate a characterisation factor for the chemical in question. Within the OMNIITOX project consortium it has been decided that the ecotox effect indicator for the BM should be able to work on minimum three measured EC50 acute laboratory test data. The main reason for this decision is that the BM should be able to work on a significant number of chemicals today and be in accordance with the most likely data availability in the near future as defined by the proposed EU chemicals policy REACH. The focus in this report is therefore on an ecotox effect indicator that is able to work on only three EC50 values and only the freshwater pelagic compartment is dealt with here. For about a year discussions have been going on within the ecotox task force established within the OMNIITOX consortium, especially about which estimation principle to choose, i.e. whether it should be no-effect based (PNEC) or effect based (e.g. median or geometric mean). As a starting point existing approaches used within LCIA has been described and evaluated. Reports on these two issues (estimation principle and evaluation of existing approaches) are enclosed with this report as possible sources for background information. In this report further theoretical elaboration of effect based average approaches (arithmetic mean, geometric mean and median) and the non-effect based approach (PNEC, here only as lowest EC50 in the dataset) are done focusing on their statistical robustness and the possibility to relate the effect indicator (based on a measure of effect rather than a no-effect measure) to damage on the endpoint, the ecosystem. The approaches are also tested for their robustness in estimating HC50 in a practical test on datasets from eleven different substances comprising seven different toxic modes of action (TMoA). On the basis of the theoretical considerations and the results of the practical test of the different approaches, the following recommendations are given for the estimation principle of the ecotox effect indicator: •The indicator is based on the GM-trophic calculated as the geometric mean (HC50) of three EC50 values, one

from each of the three trophic levels, primary producers, primary consumers and secondary consumers comprising three different taxa, i.e. algae, crustacean (invertebrates) and fish •If more than one EC50 value from each trophic level is available then the GM-trophic is calculated on the basis of the geometric means for each trophic level (GM-trophic-levels). The GM-trophic-levels is calculated as the geometric mean of the geometric means at the genus level (GM-genuses) which again are calculated as the geometric means of the geometric means at species level (GM-species). GM-species is calculated as the geometric mean of the single EC50 values for each species •As limit values around the GM-trophic, the lowest EC50 value is used as the lower limit and the highest EC50 value as the upper limit in data sets with only three EC50's values, i.e. one from each trophic level •If more than one EC50 value from each trophic level is available then the limit values around the GM-trophic are based on the three GM-trophic-level values, i.e. the lowest GM-trophic-level value is used as the lower limit and the highest GM-trophic-level value as the upper limit It is recommended to use EC50chronic values when possible but as only acute data will be available in most cases, the use of best estimate assessment factors are recommended to extrapolate from acute to chronic values. Even though there is a need for research in this area, an acute to chronic ratio of 10 between HC50acute and HC50chronic is recommended as a starting point. For several reasons (i.a. the fact that one of the main applications of the ecotox effect indicator is LCIA where the results are used in a comparison between substances), it is recommended only to use test results from laboratory tests, fulfilling certain standard conditions, e.g. standard organism and test duration restrictions. The ability of a geometric mean to represent the toxicity of very toxic substances and very sensitive species has not been dealt with yet, and further research is needed here. However, it may be anticipated on the basis of the results from the practical test of different average approaches on substances with different TMOA, that the GM-trophic with its limit values at least to some degree accounts for very toxic substances if representative toxicity data are available.

#### **General information**

State: Published

Organisations: Department of Management Engineering

Authors: Larsen, H. F. (Intern), Payet, J. (Ekstern), Molander, S. (Ekstern), Hauschild, M. Z. (Intern)

Number of pages: 56

Publication date: 2004

#### **Publication information**

Publisher: European Commission,

Original language: English

Main Research Area: Technical/natural sciences

Links:

<http://www.ipl.dtu.dk/publikation/8354/dk/>

Source: orbit

Source-ID: 177950

Publication: Research › Report – Annual report year: 2004

### **Implementation of the OMNIITOX Base Model: Contribution to work package 8 of the OMNIITOX project as part A of appropriate deliverable D41. Part VIII – Implementation of the ecotoxicological effects module**

#### **General information**

State: Published

Authors: Larsen, H. F. (Intern), Payet, J. (Ekstern), Molander, S. (Ekstern), Hauschild, M. Z. (Ekstern)

Publication date: 2004

#### **Publication information**

Original language: English

Main Research Area: Technical/natural sciences

#### **Bibliographical note**

EC Project contract G1RD-CT-2001-00501

Publication: Research - peer-review › Report – Annual report year: 2004

### **Including chemical-related impact categories in LCA on printed matter does it matter?**

Introduction Existing product Life Cycle Assessments (LCA<sub>i</sub>'s) on offset printed matter all point at paper as the overall dominating contributor to the impacts from the life-cycle of this category of products. This dominating role of paper is primarily founded in the energy-related impact categories global warming, acidification and eutrophication. The studies focus on energy consumption including the emissions and impact categories related to energy. The chemical-related impact categories comprising ecotoxicity and human toxicity are not included at all or only to a limited degree. In this paper we include these chemical-related impact categories by making use of some of the newest knowledge about emissions from the production at the printing industry combined with knowledge about the composition of the printing materials used during the production of offset printed matter. This paper is based on the report "Life Cycle Assessment of generic printed matter from a fictitious sheet fed printing industry" [1] which is going to be published by the Danish EPA as part of the project "Ecolabelling of printed matter". Goal and scope The goal of the study is to identify the distribution of potential environmental impacts and consumption of resources along the life cycle of a generic printed matter produced on a



fictitious sheet feed offset printing industry in Europe. The results are to be used for developing ecolabelling criteria. Main activities at all stages in the life cycle are covered. However special focus is on the production stage but upstream emissions assessed to be of possible significant importance are included (e.g. estimated emissions from pigment production) or handled in the sensitivity analysis. The functional unit is 1 ton of sheet feed offset produced printed matter, i.e. printed communication covering books, pamphlets etc. As time scope for the production stage 1990 to 2002 is chosen and as technological scope mainly modern technology (not state-of-the-art) used at least in Northern Europe is used. Marginal approaches are used for production of electricity (natural gas) and paper production (virgin fibres) as the main approach i.e. in the reference scenario. In all other cases an average approach is used. The consumption of raw materials at the fictitious printing industry is mainly based on average values for 10 to 70 Swedish and Danish offset printing industries. The range in the consumption of the most important raw materials is typically well below or just above a factor of about 10. Method The EDIP method is used [2]. The impact assessment comprises classification, characterisation, normalisation and weighting. Danish/global normalisation references and weighting factors (Wenzel et al. 1997) are used in the reference scenario and European/global ones [3] are used for sensitivity analysis. The weighting factors for the impact categories are based on political reduction targets. Conclusion „The distribution of potential environmental impacts along the life cycle of a generic printed matter produced on a fictitious sheet feed offset printing industry in Europe has been identified and shown in Figure 1 (light bars). „The effect of including the chemical related impact categories is substantial as shown in Figure 1, e.g. the importance of paper is reduced from 67% to 31% and the importance of printing increased from 10% to 41%. „On the basis of sensitivity analysis it is concluded that the results of this LCA study is valuable for ecolabelling of offset printed matter (especially sheet fed) at both a Nordic scale (Swan labelling) and a European scale (Flower labelling). Furthermore, on the basis of the alternative scenarios and sensitivity analysis done it is concluded that the strength for use in ecolabelling of printed matter of the LCA approach used here is not only the exact LCA profile of the reference scenario based upon average values but to a high degree the possibilities to use sensitivity analysis based upon known or theoretical ranges within values on consumption, emissions or other parameters. By doing sensitivity analysis we get an indication on how sensitive the distribution of the potential impact within the life cycle of the printed matter is to variation in the parameter in question and thereby guidance in how much weight to put on the parameter in the development of ecolabelling criteria. References [1]Larsen, H.F., Hansen, M.S., Hauschild, M. (2004). Life Cycle Assessment of generic printed matter from a fictitious sheet fed printing industry. DRAFT April 2004. Part of the project „Ecolabelling of printed matter“ which is going to be published by the Danish EPA in summer 2004. [2]Wenzel, H., Hauschild, M., & Alting, L. (1997) Environmental Assessment of Products, Vol. 1. First edn. Chapman & Hall [3]Stranddorf, H.K., Hoffmann, L., Schmidt, A. (2004). LCA Guideline: Update on impact categories, normalisation and weighting in LCA. Selected EDIP97-data. Final draft February 2004. To be published as an Environmental Project by the Danish EPA. Figure 1 Comparison of weighted LCA profiles with or without chemical related impact categories included (percentage of total, milli-person-equivalents-targeted, mPET). For „Total paper (net)“ the avoided energy consumptions and emissions due to incineration and recycling of paper is allocated to paper.

### General information

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering, Institute for Product Development

Authors: Larsen, H. F. (Intern), Hansen, M. S. (Ekstern), Hauschild, M. Z. (Intern)

Publication date: 2004

### Host publication information

Title of host publication: DK2

Main Research Area: Technical/natural sciences

Conference: Dansk Kemiingeniørkonference, Lyngby, Denmark, 24/05/2004 - 24/05/2004

Source: orbit

Source-ID: 177952

Publication: Research - peer-review › Article in proceedings – Annual report year: 2004

### Evaluation of Selection Methods for use in Life Cycle Impact Assessment

Today very few LCA studies include ecotoxicity and human toxicity in the impact assessment and if they do it is typically highly incomplete. The reason for this seems to be that in many cases an extremely high number of chemical emissions from the inventory potentially contribute to the toxicity related impact categories and only for a small part of them there are characterisation factors provided by the applied impact assessment method. This calls for a method that is able to select/prioritise those chemical emissions that contribute significantly to the toxicity related impact categories. Such a method is called a selection method and its overall aim is to focus the effort on significant chemical emissions when Life Cycle Impact Assessment is done on toxic releases. Today experience from application of the few existing selection methods is very sparse and the need for research within this area therefore seems urgent. This paper will present the result of a comparison between different selection methods (e.g. CPM-selection and profactor) including a partial order ranking method called Hasse diagram technique. Furthermore a characterisation method (EDIP) is included in order to compare the ranking of the selection methods with the results of a characterisation. The data used for this comparison comprises a test set of around 80 different substances covering all relevant combinations of different substance properties through representatives of different substance groups, i.e. non-dissociating organics, dissociating organics, amphiphilics, metals and other inorganics. This test set has been developed within the EU project OMNIITOX for a structured comparison of characterisation methods and selection methods. The comparison includes an identification of differences in ranking between the different methods and an analysis of the causes to the observed differences.

### General information

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Birkved, M. (Intern), Hauschild, M. Z. (Intern)

Keywords: (Chemicals, ecotoxicity, Selection methods, life cycle impact assessment)

Publication date: 2003

### Host publication information

Title of host publication: SETAC Europe 13th Annual Meeting Hamburg, Germany, 27 April - 1 May 2003: Abstracts

Place of publication: Brussels

Publisher: SETAC Europe

Editor: S.

Main Research Area: Technical/natural sciences

Conference: SETAC Europe 13th annual meeting : Understanding the complexity of environmental issues. A way to sustainability, Hamburg, Germany, 27 april - 1 may, 01/01/2003

Source: orbit

Source-ID: 63565

Publication: Research › Article in proceedings – Annual report year: 2003

### Environmental profiles on chemicals (EPC): A substitution tool i.a. used in the textile industry

When dealing with cleaner technology and product development within industries using a lot of different chemicals, substitution is essential. In many cases substitution of hazardous chemicals with less hazardous ones will diminish the environmental impact from the industry in question. But among many different chemicals it can be difficult to prioritize and evaluate areas for substitution. The EPC-tool was thus developed and it has been used successfully within the Danish printing industry and the Polish textile industry. The EPC tool combines key emission and key consumption figures with hazard assessments of the chemicals used in production and thus creates an environmental profile of the industry, process or product in question. The preceding EPCs are used for pointing out hazardous chemicals used in relatively high quantities and therefore candidates for substitution. The EPCs created after substitution are used for describing the improved environmental performance of the industry. The hazard assessment scoring part of the EPC-tool is used for choosing the best substitutes – from an environmental point of view – among various technically suitable candidates. Three different hazard-ranking systems were used. One for chemicals discharged into public sewage systems (environmental hazard), one for chemicals discharged directly into the aquatic environment (environmental hazard) and one for health hazard. The ranking systems are developed on the basis of the principles of environmental hazard classification as described in the EU Council Directive 67/548/EEC including its amendments. This paper will present the result from the use of the tool with in the Polish textile industry where large reductions in environmental impact have already taken place and are still going on.

### General information

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering, TI, IW

Authors: Larsen, H. F. (Intern), Hansen, J. (Ekstern), Laursen, S. E. (Ekstern), Knudsen, H. H. (Intern), Ledakowicz, J. (Ekstern), Machnowski, W. (Ekstern)

Keywords: (Substitution, Textiles, Cleaner technology, Chemical ranking and scoring CRS, Hazard assessment)

Publication date: 2002

### Host publication information

Title of host publication: Environmental profiles on chemicals (EPC): A substitution tool i.a. used in the textile industry

Place of publication: Brussels

Publisher: SETAC Europe

Main Research Area: Technical/natural sciences

Conference: 11th Annual Meeting of SETAC Europe, Madrid, Spain, 06/05/2001 - 06/05/2001

Source: orbit

Source-ID: 63268

Publication: Research - peer-review › Article in proceedings – Annual report year: 2002

### Inventory of LCIA selection methods for assessing toxic releases. Methods and typology report part B

This report describes an inventory of Life Cycle Impact Assessment (LCIA) selection methods for assessing toxic releases. It consists of an inventory of current selection methods and other Chemical Ranking and Scoring (CRS) methods assessed to be relevant for the development of (a) new selection method(s) in Work package 8 (WP8) of the OMNIITOX project. The selection methods and the other CRS methods are described in detail, a set of evaluation criteria are developed and the methods are evaluated against these criteria. This report (Deliverable 11B (D11B)) gives the results from task 7.1d, 7.1e and 7.1f of WP 7 for selection methods. The other part of D11 (D11A) is reported in another report and deals with characterisation methods. A selection method is a method for prioritising chemical emissions to be included in an LCIA characterisation of toxic releases, i.e. calculating indicator scores by a characterisation method for the impact categories covering ecotoxicity and human toxicity. A selection method is therefore not a characterisation method like the "simple base method" and the "base method" that are going to be developed within WP8 but the purpose of a selection

method is to focus the effort within characterisation. Selection methods are used within LCIA to select those chemical emissions (mapped in the inventory part of the LCA in question) that are expected to contribute significantly to the characterisation and exclude the insignificant ones. In this way only significant emissions (i.e. the selected ones) are included in the typically more data demanding and more time demanding characterisation step.

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Birkved, M. (Intern), Hauschild, M. Z. (Intern), Pennington, D. W. (Ekstern), Guinée, J. (Ekstern)

Keywords: (Chemicals, ecotoxicology, Life cycle impact assessment, Chemical ranking and scoring CRS, Selection methods, Human toxicology)

Number of pages: 118

Publication date: 2002

#### **Publication information**

Publisher: European Commission,

Original language: English

Main Research Area: Technical/natural sciences

Source: orbit

Source-ID: 63271

Publication: Research - peer-review › Book – Annual report year: 2002

#### **LCIA selection methods for assessing toxic releases**

Characterization of toxic emissions in life cycle impact assessment (LCIA) is in many cases severely limited by the lack of characterization factors for the emissions mapped in the inventory. The number of substances assigned characterization factors for (eco)toxicity included in the dominating LCA methods in use to day (e.g. Eco-indicator 99 and EDIP) is in the range of 40 – 330 and often they only cover a minor part of the substances in the inventory. The user of the LCA method should in principle be able to calculate any missing factors (if needed substance data are available which is often not fulfilled) but this task is at best very time consuming and often not possible. There seems to be a need for an easy in use and less time consuming selection/screening method based on readily available substance data. The aim of such a selection method is to prioritise those emissions (chemicals) from the inventory that contribute significantly to the impact categories on ecotoxicity and human toxicity to focus the characterisation work. The reason why the selection methods are more important for the chemical-related impact categories than for other impact categories is the extremely high number of substances potentially contributing to these categories. This paper will present the results from an inventory study on the few existing selection methods (i.e. EDIP-selection and priorfactor) and a number of relevant candidates (e.g. EURAM, WMPT, Hasse diagram) as basis for developing new selection methods. The methods are evaluated against a set of pre-defined criteria (comprising consistency with characterization and data requirement) and applied to case studies and a test set of chemicals. The reported work is part of the EU-project OMNIITOX.

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering

Authors: Larsen, H. F. (Intern), Birkved, M. (Intern), Hauschild, M. Z. (Intern)

Keywords: (Chemicals, ecotoxicology, Selection methods, life cycle impact assessment, Human toxicology)

Publication date: 2002

#### **Host publication information**

Title of host publication: LCIA selection methods for assessing toxic releases

Place of publication: Brussels

Publisher: SETAC Europe

Main Research Area: Technical/natural sciences

Conference: SETAC Europe 12th Annual Meeting, Viennea, Austria, 01/01/2002

Source: orbit

Source-ID: 63269

Publication: Research - peer-review › Article in proceedings – Annual report year: 2002

#### **Miljøoptimering af afvaskning ved tryk med vandfortyndbar flexotrykfarve**

#### **General information**

State: Published

Organisations: Innovation and Sustainability, Department of Management Engineering, DHI Denmark, EnPro ApS, dk-TEKNIK A/S

Authors: Larsen, H. F. (Intern), Helweg, C. (Ekstern), Pedersen, A. R. (Ekstern), Wallström, E. (Ekstern), Hoffmann, L. (Ekstern)

Keywords: (Chemicals, ecotoxicology, Substitution, Cleaner technology, Flexographic printing, Printing industry, Packaging industri, Waste water, Human toxicology, Water-based flexographic printing inks, Hazard assessment)  
Number of pages: 283  
Publication date: 2002

#### Publication information

Place of publication: Copenhagen  
Publisher: Miljøstyrelsen  
Original language: Danish  
Main Research Area: Technical/natural sciences  
Source: orbit  
Source-ID: 63270  
Publication: Research - peer-review › Book – Annual report year: 2002

#### Life Cycle Assessment and Risk Assessment: A Methodological Comparison.

Life Cycle Assessment and Risk Assessment are two different tools in environmental management. The paper identifies harmonies, discrepancies and relations between the two tools exemplified by the risk assessment principles of the European Commission (EC) and the LCA method 'EDIP' (En-vironmental Design of Industrial Products) developed in Denmark, respectively. A very important feature of LCA is the relative assessment due to the use of a functional unit. Risk assessment on the other hand is an absolute assessment, which may require very specific and detailed information on e.g. the exposure conditions. It is concluded that the conceptual background and the purpose of the tools are different but that there are overlaps where they may benefit from each other and they do complement each other in an overall environmental effort.

#### General information

State: Published  
Organisations: Innovation and Sustainability, Department of Management Engineering  
Authors: Olsen, S. I. (Intern), Christensen, F. M. (Ekstern), Hauschild, M. Z. (Intern), Pedersen, F. (Ekstern), Larsen, H. F. (Intern), Tørsløv, J. (Ekstern)  
Keywords: (Risk assessment, Life Cycle Assessment, Environmental management, EDIP)  
Pages: 385-404  
Publication date: 2001  
Main Research Area: Technical/natural sciences

#### Publication information

Journal: Environmental Impact Assessment Review  
Volume: 21  
ISSN (Print): 0195-9255  
Ratings:  
BFI (2015): BFI-level 1  
Scopus rating (2015): 1.436 2.057  
BFI (2014): BFI-level 1  
Scopus rating (2014): 1.427 1.68  
BFI (2013): BFI-level 1  
Scopus rating (2013): 1.16 1.791  
ISI indexed (2013): ISI indexed yes  
BFI (2012): BFI-level 1  
Scopus rating (2012): 1.356 2.005  
ISI indexed (2012): ISI indexed yes  
BFI (2011): BFI-level 1  
Scopus rating (2011): 1.855 2.352  
ISI indexed (2011): ISI indexed yes  
BFI (2010): BFI-level 1  
Scopus rating (2010): 1.183 1.679  
BFI (2009): BFI-level 1  
Scopus rating (2009): 1.059 2.285  
BFI (2008): BFI-level 2  
Scopus rating (2008): 1.175 1.751  
Scopus rating (2007): 0.99 1.518  
Scopus rating (2006): 0.804 1.83

Scopus rating (2005): 0.652 1.313  
Scopus rating (2004): 0.86 1.384  
Scopus rating (2003): 0.649 0.867  
Scopus rating (2002): 0.514 0.999  
Scopus rating (2001): 0.342 0.681  
Scopus rating (2000): 0.353 0.59  
Scopus rating (1999): 0.358 1.209  
Original language: English  
Source: orbit  
Source-ID: 63058  
Publication: Research - peer-review › Journal article – Annual report year: 2001

## **Bilvaskehaller - status og strategier**

### **General information**

State: Published  
Organisations: Department of Management Engineering, DHI Denmark  
Authors: Nielsen, U. (Ekstern), Pedersen, B. M. (Ekstern), Larsen, H. F. (Intern), Knudsen, H. H. (Intern)  
Keywords: (Cleaner technology, Environmental regulation of chemicals, Waste water)  
Number of pages: 164  
Publication date: 2000

### **Publication information**

Publisher: Miljøstyrelsen  
Original language: Danish  
Main Research Area: Technical/natural sciences  
Source: orbit  
Source-ID: 187016  
Publication: Research - peer-review › Book – Annual report year: 2000

## **Areas of intervention for cleaner technology in the Danish printing industry - focus on wastewater problems**

### **General information**

State: Published  
Organisations: VKI Water Quality Institute  
Authors: Larsen, H. F. (Intern), Tørsløv, J. (Ekstern), Damborg, A. (Ekstern)  
Keywords: (Ecotoxic Chemicals, Enviromental hazard Identification, intervention areas for cleaner tecnology, Printing industry, Scoring model, Wastewater)  
Pages: 29-37  
Publication date: 1996  
Main Research Area: Technical/natural sciences

### **Publication information**

Journal: Water Science and Technology  
Volume: 33  
Issue number: 6  
ISSN (Print): 0273-1223  
Ratings:  
BFI (2015): BFI-level 1  
Scopus rating (2015): 0.469 0.552  
BFI (2014): BFI-level 1  
Scopus rating (2014): 0.6 0.678  
BFI (2013): BFI-level 1  
Scopus rating (2013): 0.563 0.698  
ISI indexed (2013): ISI indexed yes  
BFI (2012): BFI-level 1  
Scopus rating (2012): 0.589 0.666  
ISI indexed (2012): ISI indexed yes  
BFI (2011): BFI-level 1  
Scopus rating (2011): 0.608 0.648

ISI indexed (2011): ISI indexed yes  
BFI (2010): BFI-level 1  
Scopus rating (2010): 0.547 0.605  
BFI (2009): BFI-level 1  
Scopus rating (2009): 0.593 0.646  
BFI (2008): BFI-level 2  
Scopus rating (2008): 0.585 0.696  
Scopus rating (2007): 0.755 0.781  
Scopus rating (2006): 0.704 0.793  
Scopus rating (2005): 0.774 0.86  
Scopus rating (2004): 0.885 0.917  
Scopus rating (2003): 0.88 0.898  
Scopus rating (2002): 0.903 0.885  
Scopus rating (2001): 0.758 0.968  
Scopus rating (2000): 0.765 0.895  
Scopus rating (1999): 0.882 0.939  
Original language: English  
Source: orbit  
Source-ID: 317774  
Publication: Research - peer-review › Journal article – Annual report year: 1996

#### **Projects:**

#### **LC-IMPACT: Development and application of environmental Life Cycle Impact assessment Methods for imProved sustAinability Characterisation of Technologies**

Department of Management Engineering  
Quantitative Sustainability Assessment  
Radboud Universiteit  
Swiss Federal Institute of Technology  
Swedish Institute for Food and Biotechnology  
PRé Consultants B.V.  
International Institute for Applied Systems Analysis  
Unilever  
University of Stuttgart  
Quantis  
Leiden University  
European Commission - Joint Research Center  
Institute of Agri-food Research and Technology  
University of Bayreuth  
Period: 01/12/2009 → 31/05/2013  
Number of participants: 6  
Keywords: (LCA)  
Acronym: LC-IMPACT  
Project participant:  
Hauschild, Michael Zwicky (Intern)  
Rosenbaum, Ralph K. (Intern)  
Larsen, Henrik Fred (Intern)  
Fantke, Peter (Intern)  
Owsianiak, Mikolaj (Intern)  
Cosme, Nuno Miguel Dias (Intern)

## **Relations**

Parent project:

Development and application of environmental Life Cycle Impact assessment Methods for improved sustainability

Characterisation of Technologies

Project

## **Operational Models and Information tools for Industrial applications of eco/TOXicological impact assessments**

OMNIITOX is a EU-project under the "Competitive and Sustainable Growth"-programme, running from 2001 to 2004.

OMNIITOX 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 (LCA) and (Environmental) Risk Assessment (ERA).

Department of Management Engineering

Period: 01/04/2001 → 01/01/2005

Number of participants: 4

Project participant:

Larsen, Henrik Fred (Intern)

Birkved, Morten (Intern)

Olsen, Stig Irving (Intern)

Project Manager, organisational:

Hauschild, Michael Zwicky (Intern)

## **Financing sources**

Source: Forsk. EU - Rammeprogram

Name of research programme: Forsk. EU - Rammeprogram

Amount: 2,700,000.00 Danish Kroner

Project

## **Kemikalieorienteret produktvurdering**

Department of Management Engineering

Period: 01/01/2001 → 11/02/2005

Number of participants: 5

Phd Student:

Larsen, Henrik Fred (Intern)

Main Supervisor:

Hauschild, Michael Zwicky (Intern)

Examiner:

Kusk, Kresten Ole (Intern)

Chapman, Peter M. (Ekstern)

Molander, Sverker (Ekstern)

## **Financing sources**

Source: Internal funding (public)

Name of research programme: Anden sektorministeriel finans

Project: PhD