RIGA TECHNICAL UNIVERSITY
Faculty of Power and Electrical Engineering
Institute of Energy Systems and Environment

Jana SIMANOVSKA
Doctoral Program in Environmental Science

AN ECODESIGN METHOD TO REDUCE ADVERSE EFFECTS OF CHEMICALS DURING PRODUCT LIFE CYCLE

Summary of thesis

Scientific supervisors
Dr.sc.ing., professor
G. BAŽBAUERS

Dr.chem., docent
K. VALTERS

Riga 2012

UDK 502.131.1 (043.2)
Si 530 e

Simanovska J. An ecodesign method to reduce adverse effects of chemicals during product life cycle. Summary of PhD thesis. -R.:RTU, 2012.-31 page

Published in accordance with the resolution of RTU, Institute of Energy Systems and Environment, protocol Nr. 19, 12 January 2012

ISBN 978-9934-8302-4-2

This work has been supported by the European Social Fund within the project "Support for the implementation of doctoral studies at Riga Technical University"

DISSERTATION PROPOSED FOR DR.SC.ING. IN ENVIRONMENTAL ENGINEERING DEGREE AT RIGA TECHNICAL UNIVERSITY

This study is proposed for attaining the degree of Doctoral Degree in Environmental Engineering (Dr. Sc.ing.) and will be defended on June 26th, 2012 at 15^{00} at the Faculty of Power and Electrical Engineering, 1 Kronvalda bulvaris, room 21.

OFFICIAL OPPONENTS

Professor, Dr.sc.ing. Viesturs JANSONS
Latvian University of Agriculture

Dr. geogr. Ilga KOKORĪTE
Latvian University

Dr.sc.ing. Visvaldas VARŽINSKAS
Technological University of Kaunas, Lithuania

Confirmation statement

I, the undersigned, hereby confirm that I have developed this dissertation, which is submitted for consideration at Riga Technical University for attaining the degree of Dr. Sc. Ing. in Environmental Engineering. This study has not been submitted to any other university or institution for the purpose of attaining scientific degrees.

Jana Simanovska …………………………….

Date: ………………………

This dissertation is written in Latvian and contains: introduction, four chapters, conclusions, bibliography, 39 figures, 41 table and 132 pages. The bibliography contains 249 references.

TABLE OF CONTENT

BACKGROUND

The development of the chemicals industry shows a rapidly increasing trend – according to the data of the World Health Organization, the growth rate of chemical industrial production is over ten times during the last forty years [1]. Some of these chemicals are included as part of the products and are released from them during the use of those products. However, neither science, nor legislation is able to cope with the rates of chemical production [2,3], resulting in the public concern about the consequences caused by chemicals in the products. There is growing scientific evidence on hazards to the environment and human health related to leaching of hazardous substances contained in products [4,5,6]. An increasing incidence of human cancer cases can be attributed to outdoor and, specifically, indoor pollution with chemical substances [4]. Hwang et al., 2008 disputes the assumption that the main pathway for endocrine disrupting substances into the human body is through the intake of food. He concludes that the indoor air and dust may play a similar role such as food in the intake of endocrine disrupting substances into the human body, especially for children, and the indoor concentrations of certain hazardous substances can exceed the outdoor concentrations up to a thousand times [5]. Even several years after the removal of the persistent hazardous substances from the market, the indoor pollution still remains at the same level due to continuing release from the products containing these substsances as it was concluded in a study on indoor air concentrations of currently restricted short chain chlorinated paraffins [6].

Additional evidence shows elevated levels of brominated flame-retardants in the bodies of Arctic animals [7,8] can be caused by releases from the products rather than the emissions from the production processes. The observed decrease in concentration of certain contaminants is likely the result of policy developments, however, with regard to persistent substances, the adverse effects persist long after the pollution has ceased or has been greatly reduced, as is the case of lindane and DDT [9].

The toxic impacts of chemicals are high on the political agenda for already about half a century, leading to ambitious political targets. Despite these political activities, however, the World Health Organisation (WHO) still attributes more than 25% of the global burden of diseases to environmental factors, among them – pollution from hazardous chemical substances [1]. The WHO research "Limits to growth", a highly valued contribution to environmental policy, points out that the introduction of policy measures and investments in environmental protection have not been able to compensate the pressure on the environment caused by the growing human population and its consumption [10]. The environmental policy of the European Union contributes to the prevention of pollution during the design process of the products by incorporating ecodesign principles and manufacturer's responsibility for the impacts of production on the environment and human health throughout the product life cycle into legislation. The manufacturer's responsibility lies not only at the production process level, but extends to the use of the products and the end of life, including waste landfilling, recovery or recycling. Thus, the methods and skills for environment-friendly product development is a topical research theme.

Ecodesign is not limited to compliance with environmental regulations, but it helps businesses to be proactive and to develop products with high environmental performance, which is attractive due to increasing sales of green products. In order to achieve more proactivity from businesses, there is a need to investigate those areas where it is desirable to be proactive, as well as offer ecodesign methods to assist companies in developing new products. On another hand, by the time the legislation becomes more stringent. So that a proactive enterprise has a market advantage due to timely identification and and elimination of potential complications in the future, if the new legislation sets more stringend requirements. Many ecodesign strategies set the reduction of toxic effects as an important ecodesign goal, however, there are skeptical assessments of the current level of implementation to a large extent due to the lack of information on chemicals in the supply chain [11,12].

The doctoral thesis is devoted to research on how to reduce the adverse impact on the environment and the health of consumers caused by chemicals in products by applying ecodesign during project development.

OBJECTIVES AND TASKS

The goal of the research was to develop an ecodesign method to reduce the adverse effects of harmful chemical substances on the environment and human health during the product life cycle. To reach the objective it was necessary to perform the following tasks:

- Develop a criteria system for evaluation of materials and elaboration of ecodesign proposals, considering the properties of the toxic substances, re-use and recovery opportunities, design parameters and product life cycle.
- Develop principles for the verification of information on hazardous substances delivered by up-stream suppliers to enable the collection of reliable information.
- Validate the ecodesign method with the help of several case studies showing the application of the method and the feasibility for information collection via the supply chain.

RESEARCH METHODOLOGY

The doctoral thesis consists of four parts: the first part is devoted to a literature review on the availability of ecodesign methods to reduce toxic impacts and to promote the reuse and recycling of materials. The second part introduces the methods applied during the research, as well as the principles of elaborating a new ecodesign method. The third part describes several pilot studies, approbating the new ecodesign method. In the fourth part, the results are discussed and compared with the literature data.

In the development of the ecodesign method, the principles of the multi-criteria decision methods are applied. To elaborate a ranking system of chemicals hazards, the Globally Harmonized System of chemicals classification (GHS, [13]) is used. Since the chemical impurities impact the possibilities for material recovery and a large part of the necessary information is obtainable through the materials supply chain, material re-use and recovery assessment was integrated in the ecodesign method. In order to single out the most essential aspects with regard to the chemicals exposure, the principles of the chemicals risk assessment are applied. The method is supplemented by the information verification scheme to guarantee reliability of information necessary to run the ecodesign method.

The ratings for the criteria system of the evaluation of sound material use were developed based on the literature analysis and development of the worst- and best-case scenarios. The elaborated information verification scheme is tested within a case study on wood products treated with preservatives, involving ecotoxicological and chemical testing. For approbation of the ecodesign method, several case studies are performed and the results are compared with the conclusions drawn by a life cycle assessment study performed within the doctoral theses for the same products.

SCIENTIFIC AND PRACTICAL SIGNIFICANCE

The doctoral thesis expands the knowledge of scientific research regarding ecodesign methods and offers to eliminate the identified deficiencies with a new ecodesign method - a materials evaluation criteria system based on principles of the multi-criteria decision making methods, considering properties of chemical additives, properties of materials, design and life cycle.

The main scientific novelty of this method:

- Bridging the needs of product development for prompt, resource-saving decision making with scientific chemical risk assessment principles;
- A ranking system to evaluate chemical hazards based on chemicals classification, exposure to releases of chemical substances from products, and recycling patterns of the materials in order to enable generation and evaluation of ecodesign proposals leading to better protection of the man and environment, and resource saving.

Practical significance: a new ecodesign method is developed, which includes the principles of information verification. The results of the doctoral thesis can be used by manufacturing companies aiming to develop new products with higher environmental performance, as well as by experts organising green procurement processes to obtain knowledge on how to assess the products.

APPROBATION

The methodologies, advancement of the work and results of this dissertation have been thoroughly documented and discussed:

CONFERENCES:

1. Simanovska J., Bažbauers G., Valters K., Chemical risk communication from the ecodesign perspective: legislative preconditions and needs for more information than required by law, SETAC Europe 21st Annual meeting, Italy, Milan, May 15 - 19, 2011.
2. Simanovska J., Bažbauers G., Valters K., Set of criteria for environmentally sound material choice as an eco-design tool, SETAC Europe 20th Annual meeting, Spain, Seville, May 23 -27, 2010.
3. Romagnoli F., Simanovska J., Bažbauers G., Veidenbergs I., Aspects of the Allocation Problem and Boundary Assessment in Life Cycle Assessment of Latvian Pellet Flow Chain, SETAC Europe 20th Annual meeting, Spain, Seville, May 23-27, 2010.
4. Grigale Z., Simanovska J., Kalniņš M., Dzene A., Tupureina V., Biodegradable packaging from life cycle perspective, SETAC Europe 20. gadskārtējā konference, Spānija, Seviļja, 2010. gada 23. - 27. maijs.

5. Simanovska J., Romagnoli F., Valters K., Bažbauers G., Teaching of Life Cycle Assessment in RTU – Current Situation and Future Perspective, 3rd International Conference: Environmental Science and Education in Latvia and Europe: Education and Science for Climate Change Mitigation, Riga, October 23, 2009.
6. Rēpele M., Simanovska J., Valters K., Bažbauers G., Development of a Software-Based Laboratory Work for Teaching of Eco-Design, 3rd International Conference: Environmental Science and Education in Latvia and Europe: Education and Science for Climate Change Mitigation, Riga, October 23, 2009.
7. Simanovska J., Valters K., Bažbauers G. Development of set criteria as an eco-design tool for the evaluation of environmental impact of material choice, 50th Scientific conference of RTU, Session on Environmental Engineering, Riga, October 14 -15, 2009.
8. Simanovska J., Šteina M., Valters K., Bažbauers G. The environmental impacts of a desktop computer: influence of choice of functional unit, system boundary and user behaviour, 50th Scientific conference of RTU, Session on Environmental Engineering, Riga, October 14 -15, 2009.
9. Njakou D., Simanovska J., Bažbauers G., Valters K., Life Cycle Assessment and Eco-Indicators Environmental Impact For Latvian Power Supply Mix, SETAC Europe 19th Annual meeting, Goteborg, Sweden, May 31 – June 4, 2009.
10. Bažbauers G., Simanovska J., Valters K., Legislative developments and ecodesign tools for reduction of chemical risks, 49th Scientific conference of RTU, Session on Environmental Engineering, September 14-16, 2008.
11. Bažbauers G., Simanovska J., Valters K., Information System on Substances in Products and Raw Materials as an Important Step to Reach Compliance with RoHS Directive in a Company, Conference: Electronics Goes Green 2008+ - Merging Technology and Sustainable Development; Berlin, Germany, September 7-10, 2008.
12. Bažbauers G., Njakou D., Simanovska J., Valters K., Analysis of suitability of existing ecodesign tools for chemical risk reduction, SETAC Europe 18th Annual Meeting, Poland, Warsaw, May 25-29 2008.
13. Kazerovska K., Simanovska J., The role of non-governmental organisations in consumer education on chemical risks, the 2nd International conference „Environmental Science and Education in Latvia and Europe", Latvia, Riga, March 14, 2008.

PUBLICATIONS IN SCOPE OF THE DEVELOPMENT OF DOCTORAL THESIS

1. Simanovska J., Valters K., Bažbauers G. Development set of criteria as an eco-design tool for the evaluation of environmental impact of material choice // Scientific Journal of Riga Technical University, Ser. 13, Environmental and Climate Technologies, Vol. 3., 2009, p. 102-110.
2. Simanovska J., Šteina M., Valters K., Bažbauers G. The environmental impacts of a desktop computer: influence of choice of functional unit, system boundary and user behaviour // Scientific Journal of Riga Technical University, Ser. 13, Environmental and Climate Technologies, Vol. 3., 2009, p. 111-118.
3. Bažbauers G., Simanovska J., Valters K., Information System on Substances in Products and Raw Materials as an Important Step to Reach Compliance with RoHS Directive in a Company // Electronics Goes Green 2008+. Merging Technology and Sustainable Development; Conference Proceedings, Electronics Goes Green 2008+, Germany, Berlin, September 7-10, 2008, p. 149-152.
4. Bažbauers G., Njakou D., Simanovska J., Valters K., Eco-indicators of environmental

impact for Latvian power supply system// Scientific Journal of Riga Technical University, Ser.13, Environmental and Climate Technologies, Vol. 3., 2008, p. 88-94.

5. Bažbauers G., Simanovska J., Valters K. Legislative developments and ecodesign tools for reduction of chemical risks // Scientific Journal of Riga Technical University, Ser.13, Environmental and Climate Technologies, Vol. 3., 2008, p. 81-87.
6. Grigale Z., Simanovska J., Kalniņš M., Dzene A., Tupureina V. Biodegradable Packaging from Life // Scientific Journal of Riga Technical University, Ser. 1, Material sciences and applied chemistry, Vol. 21, 2010, p. 90-96.
7. Putna I., Simanovska J., Valters K., Bažbauers G., Purviņa S., Balode M. Ecotoxicity of leachates from wood materials treated with wood preservatives // Abstract book, 6th SETAC World Congress/SETAC Europe 22nd Annual Meeting, Germany, Berlin, May 20-24, 2012. – p. 405.
8. Simanovska J., Bažbauers G., Valters K., Chemical risk communication from the ecodesign perspective: legislative preconditions and needs for more information than required by law// Abstracts of SETAC Europe 21st Annual Meeting, Milano, Italy, May 15-19, 2011, MO 381.
9. Bažbauers G., Simanovska J., Rēpele M., Valters K. Ecodesign-Opportunity for Interdisciplinar Education // 4th International Conference „Environmental Science and Education in Latvia and Europe": Conference Proceedings. From Green Projects to Green Society, Latvia, Jelgava, October 22, 2010, p. 21.-22.
10. Simanovska J., Bažbauers G., Valters K., Set of criteria for environmentally sound material choice as an eco-design tool //Extended Abstracts of SETAC Europe 20th Annual Meeting, Spain, Seville, May 23-27, 2010, p. 447-448
11. Romagnoli F., Simanovska J., Bažbauers G., Veidenbergs I. Aspects of the Allocation Problem and Boundary Assessment in Life Cycle Assessment of Latvian Pellet Flow Chain // Strengthening Uncertainty Analysis in LCA, Abstracts of SETAC Europe 20th Annual Meeting, Spain, Seville, May 23-27, 2010, p. 390.
12. Grigale-Soročina Z., Simanovska J., Kalniņš M., Tupureina V., Dzene A. Biodegradable Packaging from Life Cycle Perspective // Programme of SETAC Europe 20th Annual Meeting „Science and Technology for Environmental Protection" (TH 177), Spain, Seville, May 23-27, 2010, p. 196.
13. Rēpele M., Simanovska J., Valters K., Bažbauers G. Development of a Software-Based Laboratory Work for Teaching of Eco-Design // Conference Proceedings: 3rd International Conference: Environmental Science and Education in Latvia and Europe: Education and Science for Climate Change Mitigation, Latvia, Riga October 23, 2009, p. 80-81.
14. Simanovska J., Romagnoli F., Valters K., Bažbauers G., Teaching of Life Cycle Assessment in RTU. – Current Situation and Future Perspective // Conference Proceedings, 3rd International Conference "Environmental Science and Education in Latvia and Europe", Latvia, Riga, October 23, 2009, p. 83-84.
15. Grigale Z., Tupureina V., Dzene A., Simanovska J. Life Cycle Assessment of Biodegradable Packaging // Programme and Proceedings of Baltic Polymer Symposium 2009, Latvia, Ventspils, September 22-25, 2009. p. 29
16. Njakou D., Simanovska J., Bažbauers G., Valters K. Life Cycle Assessment and Eco-Indicators Environmental Impact For Latvian Power Supply Mix // Abstract book of SETAC Europe 19th Annual Meeting, SETAC Europe 19th annual meeting, Sweden, Göteborg, May 31 -June 4, 2009, p. 126.
17. Bažbauers G., Njakou D., Simanovska J., Valters K. Analysis of suitability of existing

ecodesign tools for chemical risk reduction // Abstract book of SETAC Europe 18th annual meeting, SETAC Europe 18th Annual Meeting, Poland, Warsaw, May 25-29, 2008, p. 152.
18. Kazerovska K., Simanovska J., The role of nongovernmental organizations in consumer education on chemical risks // Proceedings of the 2nd International conference „Environmental Science and Education in Latvia and Europe", Latvia, Riga, March 14, 2008, p. 68-69.

OTHER IMPORTANT PUBLICATIONS

1. Ruut J., Simanovska J., Analysis of the existing chemicals management system in Russian Federation, Baltic Environmental Forum (BEF), The project "Awareness raising and capacity building on chemicals control in NW RUSSIA", 2004 – 2005, Funded by Finnish Ministry of Environment, Swedish Environmental Protection Agency, Nordic Council of Ministers, 42 p., 2005 [http://www.norden.org/pub/miljo/miljo/uk/US2006416.pdf]
2. Fammler H., Simanovska J., Babre K., Laud K., Dudutyte Z., Veidemane K., Ahrens A., Reihlen A., Kruopiene J., Pavasars I., Baltic Hazardous Substances Report, 2003, "Jelgavas Tipogrāfija", Latvia, p. 52
3. Fammler H., Reihlen A., Moora H., Ahrens A., Simanovska J., Babre K., Dudutyte Z., Kruopiene J., Gittinger J., Keerberg V., Valtere S., „Managing Chemicals Risks in Enterprises", Handbook for professional users of chemicals, 2003, "Jelgavas Tipogrāfija", Latvia
4. Ed. Team: Fammler H., Veidemane K., Ruskule A., Simanovska J., Indriksone D., Kipper K., Ahrens A., *2nd Baltic State of the Environment Report based on environmental indicators,* Baltic Environmental Forum, "Gandrs", Riga, 2000, 190. p.
5. Ed. Team: Fammler H., Veidemane K., Platniece A., Simanovska J., Indriksone D., Kipper K., Ahrens A., *Baltic State of the Environment Report based on environmental indicators,* Baltic Environmental Forum, "Gandrs", Riga, 1998, 94. p.

STRUCTURE OF THE THESIS

The work consists of the introduction, four sections and conclusions. It includes 132 pages, including 39 figures, 41 tables and a bibliography with 249 literature and information sources. The whole bibliography is not included in this summary, only the sources cited hereto.

1. PART. LITERATURE ANALYSIS

This chapter summarises a literature review regarding the availability of the ecodesign tools aiming to reduce toxic impacts of products throughout their life cycle, as well as tools for sound material use and identification of hazardous substances.

The task of an ecodesign method is the integration of environmental aspects into the product development process while the information availability about the properties of the product is very limited. Life cycle assessment [14] and detailed chemical risk assessment [15] are well developed, science based methods to explore the impact of products and proceses. These methods are often aplied in the process of development of legislation and product related standards. Nonetheless, the application of life cycle assessment and detailed chemical risk assessment methods is limited due to the need for highly detailed data and the specialized knowledge necessary for the use of these methods [16-18]. Therefore product designers give preference to more simple tools such as lists, checklists and screening matrices [18].

The impact of chemicals depends on two types of factors: 1) the inherent hazardous properties of chemical substances, and 2) exposure. Therefore, the measures for the reduction of adverse impacts can be achieved by minimising factors in both areas. An important task during the ecodesign process is the identification of the undesired chemical compounds. In order to achieve the reduction of undesired toxic effects, all three aspects have to be well considered.

Three approaches can be distinguished on how chemicals are identified and assessed with ecodesign tools:

1) providing a list of undesirable substances, or providing emission limit values for concrete substances, such as guidelines for electronic product development [19], or, for example, a voluntary standard for textiles [20];
2) using a classification and labelling system for chemicals [21-25];
3) using characterisation factors of life cycle impact assessment methods [26-28]; however, the ready-made life cycle impact assessment methods usually do not include impact to human health via indoor exposure and dermal route [29]. There are some approaches developed [30] regarding exposure via indoor environment but these are not yet included in the ready-made methods.

All three types of approaches cover a different number of chemical substances. Lists of substances usually include 10-100 substances. Another approach - the use of the characterisation factors of life cycle impact assessment methods address from several hundreds of substances till several thousands [29]. This approach is used by detailed and simplified LCA (life cycle assessment) based tools. The approaches that use chemicals classification offer the most complete coverage of the relevant chemical substances. Such tools are developed for specific products (building products BASTA [21]), electrical and electronic equipment - Toxicity Potential Index [22], polymers ranking [24]. A serious problem is the lack of information about chemical additives in supply chain of materials and products [11], resulting in the poor accounting of chemicals in life cycle inventories [12]. Thus, ecodesign tools are criticised for their inability to sufficiently address the toxicity of chemicals [12]. The main tool for the identification of undesirable substances in the supply chain is hazard communication via safety data sheets and material declarations.

Concluding the analysis, the current ecodesign approaches do not sufficiently cover chemicals releases from products, especially regarding consideration of the importance of exposure. Therefore, in further research a semi-quantitative prioritisation method applicable for different types of products has been developed and applied within a several case studies.
Lack of information about harmful additives may have a negative impact on the material recycling. Since the main source of information of undesired additives is documentation provided by suppliers, verification of information has a very important role in the ecodesign process.

The research hypothesis: is it possible to elaboarate an ecodesign method that uses the limited amount of information that is available during product development phase and is based on the scientific chemical risk assessment? A multi-criteria decision matrix type approach is chosen as a basis for the development of the new method incorporating the principles of chemical risk assessment within the approach. The method is supplemented with an information verification scheme.

PART 2. RESEARCH METHODOLOGY

This chapter describes the main principles applied to develop the new ecodesign method, as well as main methods of research to assess the materials during the approbation of the ecodesign method.

2.1. THE PRINCIPLES OF DEVELOPMENT OF THE NEW ECODESIGN METHOD FOR REDUCTION OF CHEMICALS IMPACTS AND PROMOTION OF SOUND USE OF MATERIALS

In the development of the eco-design method, the principles of the multi-criteria decision methods [31] were applied. This approach starts with the formulation of targets to be achieved, followed by the identification of the most essential aspects influencing the achievement of each target, and further on providing a ranking system for these aspects e.g. criteria system.

Three targets were formulated to develop the eco-design method in order to reduce impact of chemicals on 1) human health, 2) the environment, and 3) to reduce the depletion of abiotic resources (see Table 1). The depletion of abiotic resources was included since toxic additives may have an impact on the end of the life cycle of the material, and the necessary information shall be collected mainly via the supply chain.

The relevant aspects were identified based on chemicals risk assessment principles i.e. hazard assessment and exposure assessment and considering studies on the impact of design on the potential to recycle the material. The ratings for the criteria were developed based on literature analysis and the development of worst- and best-case scenarios.

In total 18 criteria have been selected (see Table 1). The HT_0 and ET_0 characterise hazardousness based on the ranking of the hazardous properties of the substance and concentration range in the material. The criteria HT_1 - HT_5 and ET_1 – ET_4 characterise the exposure pattern e.g. assessing potential leaching of the substance from the product (HT_1, ET_1), surface area of the product (HT_2, ET_2), the circumstances enhancing leaching and exposure (HT_3, HT_4, ET_3, ET_4), and the type of the user (HT_5).

With regard to recyclability, the R_0 characterises the weight of importance of recovery and reuse of material based on characterisation factors of the life cycle impact assessment methods for the depletion of abiotic resources. Other criteria, $R_{1\text{-}6}$ characterise the impact of design and end of life scenario to the potential of material to be recovered. Thus, the criteria system favours the use of renewable materials and promotes the implementation of material hygiene or the "cradle-to-cradle" principle for non-renewable materials promoting recycling.

Table 1.

Criteria system for the evaluation of materials

Target	Group of criteria	Criterion
Reduction of human exposure to hazardous substances emitted from products, HT_x	Criterion characterising hazardousness	Presence of substances toxic to human health, HT_0
	Criteria characterising exposure	Emission of the substance from the product during the product life, HT_1 Size of surface of the material, HT_2 Air exchange rate in room, HT_3 Dermal exposure of user, HT_4 Type of user, HT_5
Reduction of environmental exposure to hazardous substances emitted from products. ET_x	Criterion characterising hazardousness	Presence of substances toxic to the aquatic environment, ET_0
	Criteria characterising exposure	Emission of the substance from the product during the product life, ET_1 Size of material surface, ET_2 Impact of conditions of use, ET_3 Impact of toxic additives on the environment at the end of product life depending on the end-of-life scenario, ET_4
Reduction of depletion of abiotic resources, R_x	Criterion character-rising importance of recycling	Weight of depletion of resources, R_0
	Criteria characterising impact of material properties, design, lifecycle	Quality of recovery, R_1 Design (sorting borders), R_2 Recognition of material, R_3 Treatment of surface, R_4 Impact of additives on the recycling at the end-of-life of the product, R_5 End-of-life scenario, R_6

In order to identify the hazardous substances and rank the hazards, the Globally Harmonised System for Chemicals Classification (GHS) [13] has been chosen since it provides a more comprehensive coverage of chemicals on the market, as for example, characterisation factors of the life cycle impact assessment (LCIA) methods. The preference of usage of chemicals classification and labelling instead of LCIA characterisation factors (CF) can be illustrated with the help of an imaginary eco-design task, which is the following: avoid in products all substances that have both types of hazardous properties - carcinogen and chronic aquatic toxicity. Screening of the EU database for harmonised chemicals classification revealed 261 entries with substances classified as carcinogen and, at the same time, as chronically toxic for aquatic organisms. For further analysis, 25 substances were selected using random number generation. Two life cycle impact assessment methods: USETox and Ecoindicators'99 were chosen to compare coverage of undesired chemicals due to the following reasons: Ecoindicators'99 is among the most frequently used tools for environmentally sound material choice, but USETox is the newest method addressing the largest number of chemical substances.

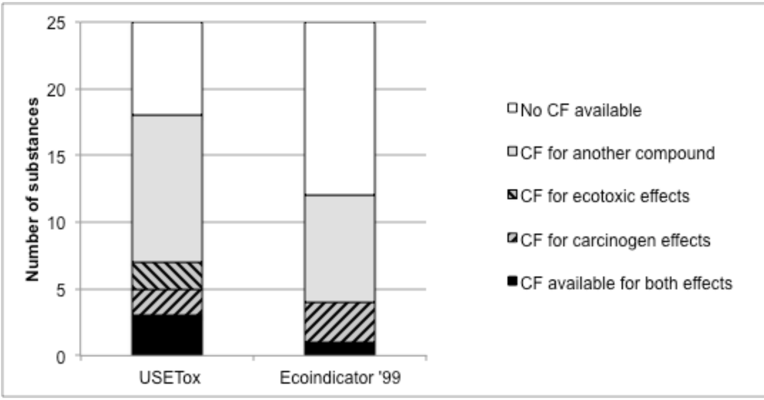


Fig. 1 Availability of characterisation factors (CF) in LCIA methods USETox and Ecoindicators'99 on carcinogen effects and aquatic ecotoxicity for the 25 selected entries that are classified as carcinogen (category 1 or 2) and chronic toxic for the aquatic environment from the EU database for harmonised chemicals classification [32]. The CF for another compound are used in cases, when the CF for the relevant CAS No. is missing, but is available for part of the compound e.g. metal ion or acid ion.

Characterization factors of the two investigated LCIA methods cover only part of the substances revealed by screening EU database for harmonised chemicals classification (see Fig. 1), using CAS numbers as the basis for the identification of substances. CAS (Chemicals Abstract Service) numbers are assigned to chemicals and are unique for each chemical substance. For many substances, only incomplete information is available e.g. only carcinogen or only ecotoxicological characterisation. In some cases, information is available for a different compound e.g. only the metal or acid ion, however, such approach requires good chemicals knowledge and disables the use of CAS numbers for the identification of substances. Although the number of substances in USETox has considerably increased compared to the Ecoindicator'99, the use of the EU harmonised classification database still provides more confidence on considering a wider range of hazardous substances.

Another important argument for choosing a classification and labelling system is easier communication via the supply chain, since this system is well known and recognised by industry due to legal requirements and global acceptance of the Globally Harmonised System of Chemicals Classification that is applied not only in the European Union, but also in other countries. In some cases the additives to the materials can be regarded as business sensitive know-how information, and producers might not be willing to disclose them. In this case, it is still sufficient for the method, if the chemical hazards are described by merely providing the classification of compounds and the concentration range. Further on the ranking grades for each criterion were developed (four grades - low impact, medium impact, high impact, and very high impact). The development process of criteria ranking may be illustrated by the example of development for ranking of hazardousness (ET_0, HT_0).

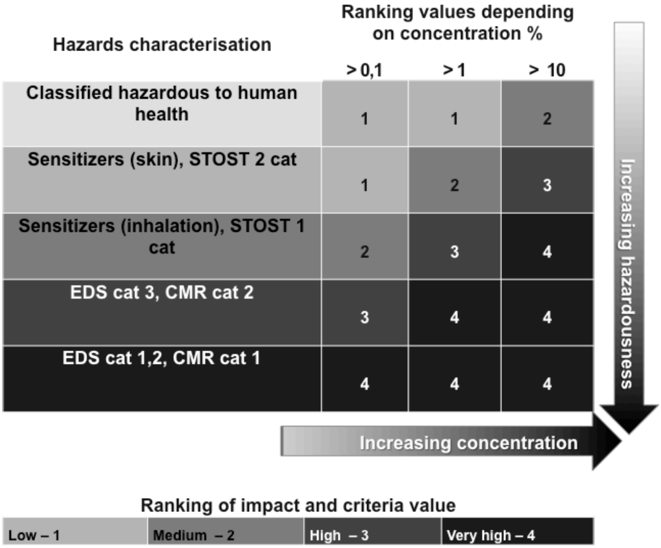
In order to elaborate a ranking system to rank hazardousness, various existing methods suitable for products have been screened [22-24], but were not chosen due to the following reasons: high ranking of physical hazards and acute toxicity hazards, since these hazards are not usually relevant for the products. The older methods also do not include endocrine-disrupting substances, and are based on the old EU chemicals classification.

In developing hazard ranking for the criterion HT_0, the toxic properties of substances were grouped according to the impact grades, starting with the most hazardous properties. Not all chemical properties pose equal risks to humans and to the environment. The highest priority in this research has been given to substances causing long-term effects even in small amounts e.g. carcinogen, mutagen, reprotoxic (CMR), endocrine disrupting substances (EDS), sensitizing, chronic target organ toxicity (STOST), as well as substances which are toxic for the aquatic environment and cause long-term impact e.g. chronic aquatic toxicity. The most severe impacts among substances with chronic aquatic toxicity are assigned to the substances that are persistent, bioaccumulative and toxic (PBT) and very persistent and very bioaccumulative (vPvB). The problem with this type of hazardous substances is, that in most of the cases there is no safe level for their presence in products [15], therefore the use of such substances should be mitigated as much as possible. With regard to the environmental hazardousness (ET_0), the most severe impacts are associated with PBT and vPvB – like substances (according to criteria defined in REACH 1907/2006, annex XIII). The rating of the substances chronically hazardous for aquatic environment follows the grades in the GHS classification. The least hazards are associated with substances which are classified as acutely toxic for the aquatic environment.

The chemicals' hazards are identified based on the GHS chemicals classification. Only in a few cases, where GHS has no specific classes yet (e.g. for persistent, bioaccumulative and toxic, and endocrine disruptors), the corresponding abbreviations PBT, vPvB and EDS are used. It can also be discussed, whether or not CMR and endocrine disrupting substsnces (EDS) are posing equal risks to human health. The risks of EDS substances are less studied and less known, since impacts of CMR substances have been under discussion for a longer period. Within this study, considering the precautionary principle, EDS are addressed with similar care as CMR until adverse impacts of the EDS are proven to be less severe than in case of CMR substances.

For ET_0 and $HT_{0,}$ hazardousness is combined with the concentration of the substance in the material. As the lower limit, the 0,1% (mass) concentration in the material has been taken since it is used in the REACH as a threshold value for the presence of substances of very high concern in the materials to be reported downstream the supply chain on the request of downstream user. Next ranking borders are 1% and 10% - since the same factor 10 is used in the GHS classification as well. In cases when the exact concentration of the substance is not known, since the product is treated with chemicals with an unknown fixation rate to the product matrix, the concentration of the substance in the auxiliary chemical is used for ranking, evaluating hazards 10 times less significant.

By combining the hazard ranking of the properties and concentration of the substance in the material or auxiliary chemicals, the final grade for the $HT_{0,}$ respectively ET_0 is developed (see Figure 2). Each substance in the material is evaluated separately. In case the substance has several hazardous properties, the ranking follows the most severe property.



Sensitizers - substances that are released into the human body, makes it particularly sensitive to this and other substances, causing allergies,
STOST - Specific target organ systemic toxicity,
EDS - Endocrine disrupting substances
CMR - carcinogenic, mutagenic, toxic for reproduction.

Fig. 2. Ranking regarding the presence of substances toxic and harmful to human health in the material (including free monomers in polymers), criterion HT_0

Similarly, by assessing the worst- and the best-case scenarios, the ranking of other criteria is developed. The development of the criteria characterising exposure follows the principles of the chemicals risk assessment. Criteria regarding recyclability assessment are based on works of other researchers [34-39], tailored to the needs of the method presented hereto. In order to characterize the weight of the depletion of abiotic resources, characterisation factors from the CML 2001 method by Guinee et al, 2002 are used [39]. Criteria characterising the impact of material properties, design and lifecycle are developed based on the indicators proposed by Otto and Wood [38], Mathieux et al. [37] and following the EU waste management hierarchy. The economic feasibility depends on whether the potential customers are ready to cover changes in the production costs. Currently, the method ranks +10% in production costs as high impact, however the customers readiness to pay depends very much on the type of product and has to be accessed based on market research. Technological feasibility has to be considered by the company's designers. The complete grading system for evaluation is presented in the tables attached to the main thesis.

The established method was supplemented by a scheme enabling systematic examination of the information to verify the information issued by the supplier, comparing those with the widely available databases [32, 40] and legislative requirements, as well as tests. Approbation of the method was done with the help of pilot studies of several industrial products demonstrating application of the method in the development of ecodesign proposals.

2.2. Information verification regarding wood treated with wood preservatives

In order to test the information verification scheme, a pilot study with wood materials treated with three wood preservatives available at retail shops was carried out (see Table 2). Samples of wood materials (birch veneer, 1,5 mm, cut in pieces of 22 x 22 mm) were treated with wood preservatives and paint in the laboratory of the Institute of Energy Systems and Environment according to the instructions provided by producers of those chemicals.

Table 2

Wood preservatives investigated during the pilot study

Name	Classification on label	Active substances
KK1	Preparation is not classified as dangerous. Contains substances dangerous for human health and environment >1%	Alkyl (c12 -16)dimethylbenzylammonium chloride, CAS Nr. 68424-85-1 Boric acid, CAS Nr. 10043-35-3
KK2	Classified as hazardous to health, health and the environment containing dangerous substances	Tebuconazole, CAS Nr. 107534-96-3 Basic copper carbonate, CAS Nr. 12069-69-1
KK3	Not classified as dangerous. Not specified hazardous substances	Not indicated

Painted wood samples after treatment with preservative were drying two days, after treatment with the paint one more day. Samples treated only with wood preservatives were drying three days. To prepare the extracts of wood samples, they were placed in 30 ml of tap water for 24 hours immediately after drying.

The hazard assessment of the wood preservatives was done based on the information provided by suppliers and cross-checked with the official data sources according to the information verification scheme.

Further on the ecotoxicological experiments assessing the toxicity of leachates of wood samples with *D.magna* – a freshwater crustacean were performed in the laboratory of the Latvian Hydrogeological Institute in accordance with the standard LVS EN ISO 6341:1996. The testorganisms *D. magna* are cultivated in the laboratory Latvian Hydrogeological Institute and fed with the algae *Scenedesmus quadricauda* from algal culture collection of the Latvian Hydrogeological institute. The LT_{50} was calculated with the PROBIT method [41]. Additionally, the chemical analysis of extracts of wood samples were performed in the laboratory of the Latvian Environment, Geology and Meteorology Centre by inductively coupled plasma mass spectrometry (ICP-MS) [42].

2.3. USE OF LIFE CYCLE ASSESSMENT TO COMPARE THE ECODESIGN PROPOSALS GENERATED

During the research a life cycle assessment study on plywood and tin traffic signs was also performed based on information provided by the producers. The life cycle assessment was carried out with help of the SimaPro software [43], the environmental impact assessment was carried out using two life cycle impact assessment methods: EDIP 2003 and Ecodindicators'99 methods (EI 99, Egalitarian version) [43]. Based on this assessment, ecodesign proposals were generated and later compared with the ecodesign proposals delivered by the ecodesign method developed within scope of the doctoral thesis.

PART 3. APPROBATION OF THE ECO-DESIGN METHOD DEVELOPED IN THE SCOPE OF THE DOCTORAL THESIS

The third part is dedicated to approbation of the developed eco-design method to check if it is an efficient tool for eco-design solutions. The piloting was done through a number of case studies on Latvian products (road signs, wood products) and complimented with the life cycle assessment study. Information on the products explored is retrieved from the manufacturers.

3.1. THE PRESENTATION OF THE ECO-DESIGN METHOD

A new ecodesign method that integrates scientific chemical risk assessment principles in an appropriate form for product development purposes has been developed. To achieve the ecodesign aims in the company, for example, control of toxic substances in products and reduction of the depletion of resources and materials by promoting reuse and recovery requires a systematic approach i.e. management system is required. Some elements are presented in management systems of advanced companies [44]. The ecodesign method proposed by this study adds two new elements to routines forming a system of materials management in the company.

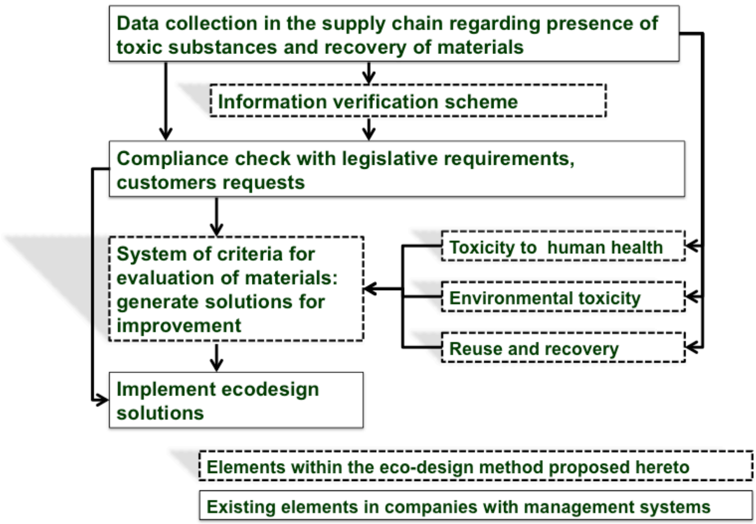


Fig. 3 Elements of the materials' management system in the company

The new element "Information verification scheme" provides a systematic framework for routine-based checking of information reliability, see Figure 4. It is developed based on analysis of the accessible and reliable information sources regarding chemicals hazard information. The flow of chemicals is accompanied with standardised safety data sheets as prescribed by law. However, there are no widely agreed standards for the material declarations. In order to evaluate materials with the criteria system introduced in this study, the company has to obtain information about all hazardous additives in the materials > 0,1 % (mass) from the suppliers.

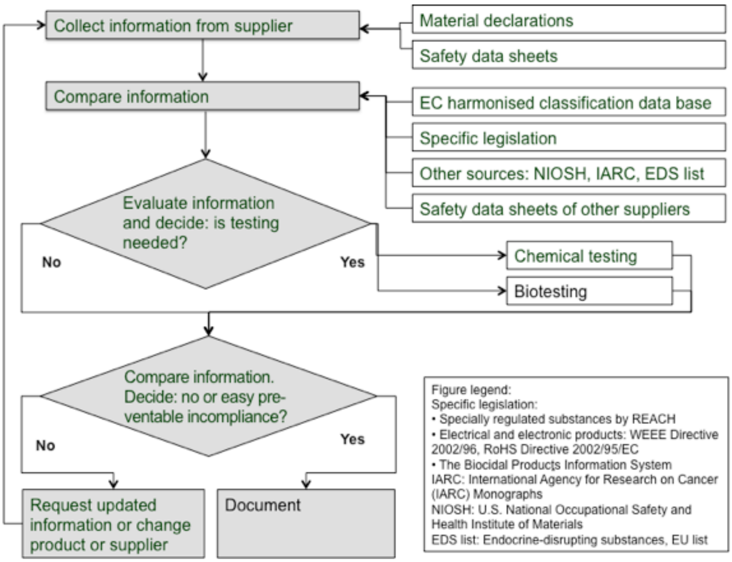


Fig. 4 Complex information verification scheme on toxic substances in chemicals and materials

The new ecodesign method presented hereto can identify the main adverse impacts on human health and the environment and helps to generate measures to reduce those adverse impacts. This system can be used in the product development process to reduce environmental impacts e.g. by choosing alternative materials or by changing the design parameters of products.

To apply the method, one has to follow the developed algorithm (see Figure 5). Firstly, one needs to assess the materials according to the ranking guidelines (available in the main thesis). Considering each criterion on a scale 1-4, it is possible to single out the important environmental and health impacts and consider options for improvement. If the material contains several harmful substances, each substance is accessed separately considering ways to reduce the toxicity or exposure.

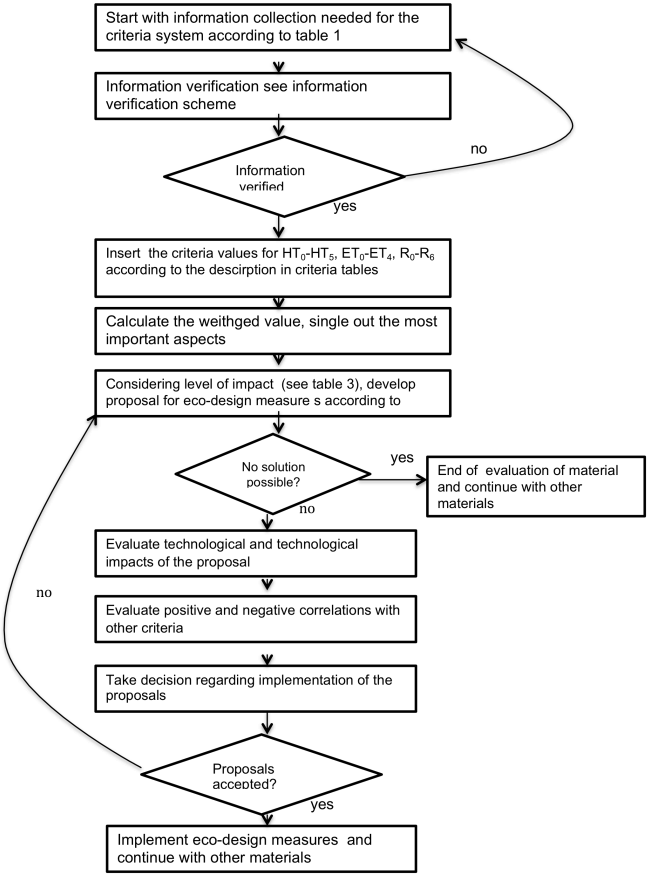


Fig. 5 General algorithm to apply the eco-design method

The priorities for action can be set with the help of the weighting process (see equation 1). In the scope of "targets to reduce human and environmental exposure to hazardous substances emitted from products", the "presence of hazardous substances" is used as a weighting factor for the criteria group, e.g. the characterisation of the intrinsic hazardousness of substances and concentration in the material. Regarding the criteria group "reduce depletion of abiotic resources" the "weight of depletion of resources" is used as the weighting factor.

$$WX_i = X_o \times X_i \qquad (1)$$

where X_o – the criteria (ET_o, HT_o or R_o)
where X_i – the criteria (ET_i, HT_i or R_i)
WX_i – weighted criteria i (WET_i, WHT_i or WR_i)

3.1. Application of information verification scheme. Use of risk communication and testing in evaluation of material toxicity

The third part describes the pilot study applying the complex information verification scheme developed within the work presented hereto. As an example, the wood samples treated with wood preservatives and paint were used.

Three water-based preservatives, available at retail stores, were chosen, all three contained different active ingredients. Only one of the products was labeled as dangerous. Eco-toxicity tests with *D.magna* in presence of all three extracts showed high toxicity to test organisms, which was the basis for further analysis of information (see fig. 6). Further examination revealed that hazard information provided by suppliers of all three preservatives contained significant inaccuracies that directly affect the safety considerations. The results of the research were communicated to the relevant state authority initiating improvement of hazard information in case of one preservative, and removal of the product from the market in case of other preservative.

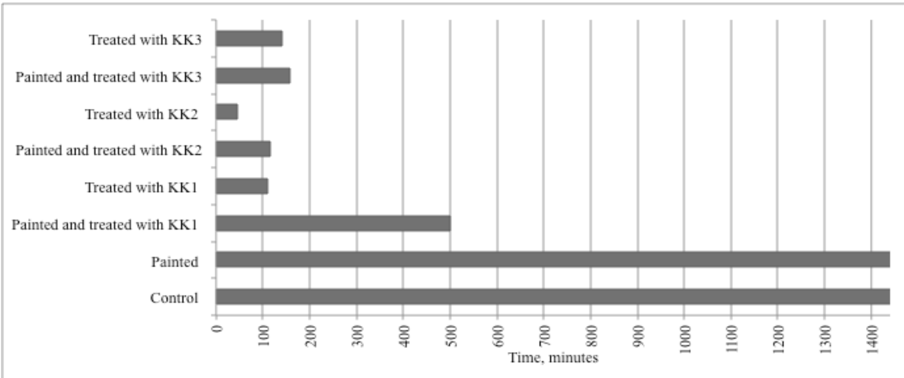


Fig. 6. Immobilisation of *D.magna* (LT_{50}) in presence of leachates from wood samples

To determine whether the experimentally obtained values of the LT_{50} in case of extracts from painted and unpainted samples are statistically significant, the two-sample mean comparison by t-test was applied. As null hypothesis H_0 the hypothesis was put forward that the mean values do not differ. The testing of the hypothesis was performed on a significance level $\alpha = 0.05$, taking into account the experimentally obtained mean values, standard deviation and the number of measurements. The necessary p-values and t values were calculated using Statgraphics software.

Chemical test of preservative KK3 by inductively coupled plasma mass spectrometry (ICP-MS) showed that KK3 contains copper and chromium compounds. When performing chemical tests of extracts of wood samples treated with KK2 and KK3 in case of painted and unpainted wood samples, it was concluded that the paint layer in case of KK2 and KK3 reduced leaching of toxic substances by 30-50%, which corresponded to literature data.

The ecotoxicological tests showed that, in case of the KK1, the paint layer is more efficient as in case of KK3 and KK2, but the magnitude was not clarified since ICP-MS is not applicable in case of organic substances.

3.2. PILOT SUDIES APPLIYNG THE ECO-DESIGN METHOD DEVELOPED IN SCOPE OF DOCTORAL THESIS FOR GENERATION OF ECO-DESIGN PROPOSALS

The application of the method is demonstrated with products from plywood, tin and wood treated with wood preservatives. Only the case of plywood is described in the summary.

Plywood was chosen due to its growing importance in the market and local production, as well as its relevance for use in consumer products. The supply chain of the studied plywood products is relatively simple, and communication routines are well established, see Fig. 7.

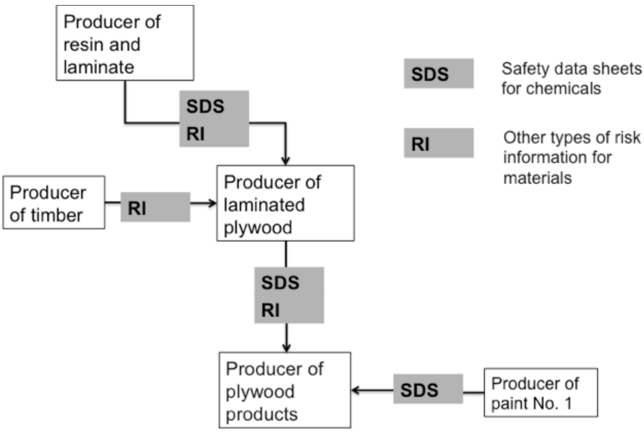


Fig. 7 Supply chain of plywood products

Application of the information verification scheme revealed an outdated classification of formaldehyde and phenol in the safety data sheets issued by the upstream producer. With regard to the classification of formaldehyde, in the EU data base of harmonised classification, formaldehyde is classified as carcinogenic category 2, but the International Agency of Cancer Research (IARC) classifies formaldehyde stronger: as carcinogen category 1.

The compliance check in the case of plywood is based on the emission tests (tested by an independent authorised laboratory commissioned by plywood producer). No emission tests are required for phenol. The norms are country specific e.g. for each client the company has to perform a compliance check based on the client's country specific requirements. There are no emission limit values for outdoor use, but with regard to indoor use, the product is compliant with the Latvian standard for plywood products. An inventory was performed for application of the criteria system, see Table 3.

Table 3

Overview on composition of laminated and painted surface of plywood (based on inventory from a company)*

Ingredients	Mass, %	Hazard classification (only classified ingredients shown)
Veneer	84,40	Not classifiable
Raw resin (total)	13,00	See classification of ingredients below
Formaldehyde	0,13	H351, H331, H311, H301, H314, H317
Phenol	0,19	H341, H331, H311, H301, H373, H314
Paper (for laminate)	0,86	Not classifiable
Resin (for laminate)	1,64	See classification of ingredients below
Formaldehyde (for laminate)	0,02	H351, H331, H311, H301, H314, H317
Water based paint (organic matter 10%)	0,14	Not classified
Butyl glycol	0,01	H332, H312, H302, H315, H319
Total	100,00	Not classifiable

* Surface 0,5 m^2, mass 3,49 kg

The assessment (Table 4) identified the following important aspects of the products made from plywood: high impact due to the presence of formaldehyde and phenol and high impact on resource depletion. Both impacts are caused due to the application of the phenol-formaldehyde resin (criteria value for HT_0 = 3 for both: phenol and formaldehyde). There is no impact regarding toxicity for the environment assessed since none of the presented substances were classified as toxic to the aquatic environment.

According to the current waste scenarios in Latvia, the discarded plywood products are deposited in landfill (criteria value: 3) despite their high energy value. The material in the products are not labelled, but easy recognisable (criteria value: 2).

With regard to human health, the situation is not alerting in case of outdoor use e.g. for a traffic sign, since direct exposure to consumers is excluded (all criteria values related to exposure are ranked as “1”, except for releases “3”). Although the formaldehyde and phenol are judged as 2nd priority for phasing out, the missing consumer exposure lowers the priority.

A different evaluation would be in case of indoor use leading to a higher priority for the changes (see Fig. 8 with four scenarios for plywood use). During the assessment it was necessary to foresee different types of indoor use (size of rooms, air exchange rate) and groups of consumers.

For indoor use, the application of the criteria system shows high relevance for the consumer’s health e.g. there is a high priority for phasing out the formaldehyde-phenol resin. If the classification of International Agency of Cancer Research (IARC) is applied, the importance to reduce emissions becomes higher.

Table 4

Results of application of criteria system for plywood foreseen for outdoor use (estimated surface 0,5 m^2).

Criteria		Value	Weighed value	Ecodesign proposals	Feasibility Techno-logical	Feasibility Econo-mical
Target: Reduction of human exposure to hazardous substances emitted from products						
Formal-dehyde	Presence of substances toxic and harmful for human health, $HT_{Formaldehyde\ 0}$	3	9	Replace current resin with glue, based on renewables	3	1
	Factors influencing binding to the product matrix, $HT_{Formaldehyde\ 0}$	3	9	Improvement of fixation rate of phenol and formaldehyde for the same type of resin	4	3
	Size of surface, $HT_{Formaldehyde\ 0}$	2	6	Considered; no proposal	-	-
	Air exchange, $HT_{Formaldehyde\ 0}$	1	3	Considered; no proposal	-	-
	Dermal exposure, $HT_{Formaldehyde\ 0}$	1	3	Considered; no proposal	-	-
	Type of user, $HT_{Formaldehyde\ 0}$	1	3	Considered; no proposal	-	-
Phenol	Presence of substances toxic and harmful for human health, $HT_{Phenol\ 0}$	3	9	Replace current resin with glue, based on renewables	3	1
	Factors influencing binding to the product matrix, $HT_{Phenol\ 1}$	3	9	Improvement of fixation rate of phenol and formaldehyde for the same type of resin	4	3
	Size of surface, $HT_{Phenol\ 2}$	2	6	Considered; no proposal	-	-
	Air exchange, $HT_{Phenol\ 3}$	1	3	Considered; no proposal	-	-
	Dermal exposure, $HT_{Phenol\ 4}$	1	3	Considered; no proposal	-	-
	Type of user, $HT_{Phenol\ 5}$	1	3	Considered; no proposal	-	-
Target: Reduction of depletion of abiotic resources						
Whole material	Weight of depletion of resources	3	9	Replace current resin with glue, based on renewables	3	1
	Quality of recovery	2	6	Considered; no proposal	-	-
	Design (sorting borders)	1	3	Considered; no proposal	-	-
	Recognition of material	1	3	Considered; no proposal	-	-
	Treatment of surface	4	12	Impossible to avoid covered surface	-	-
	Impact of additives on recycling at the end of product life	1	3	Considered; no proposal	-	-
	End of life scenario	4	12	Offer take-back of the used products for energy recovery	4	4

Ranking of impact	Low	Moderate	High	Very high
Criteria value	1	2	3	4
Weighted impact	1-2	3-4	5-10	11-16

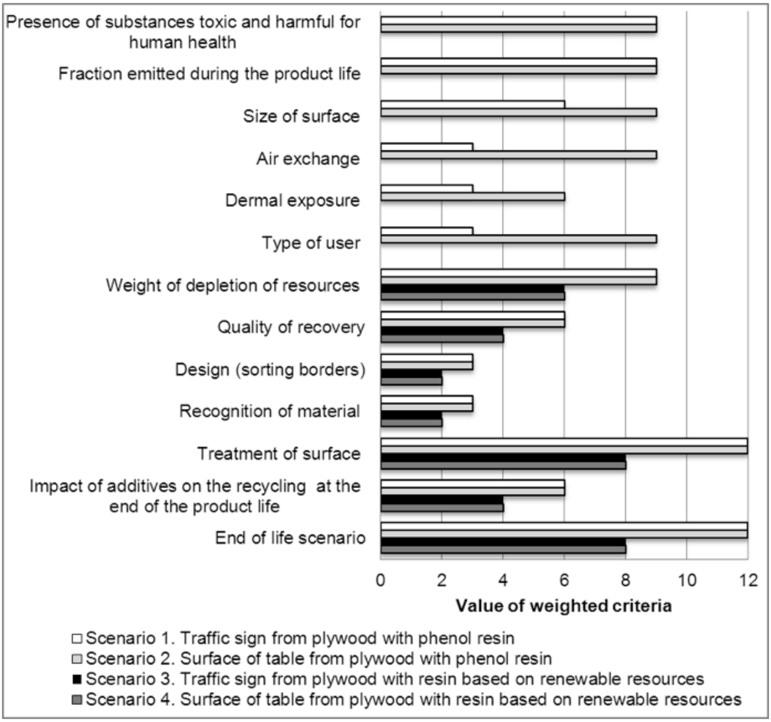


Fig. 8. Result of criteria system for products from plywood for four scenarios, as substance only formaldehyde shown. In Scenarios 3 and 4, there are no human toxicity values due to the missing presence of toxic substances

The substitution of the phenol-formaldehyde resin with a glue-based substance on renewable sources would improve upon both targets: reduce the depletion of abiotic resources and reduce impact on human health, see fig. 5. Such substitutes for the phenol-formaldehyde solution are known e.g. soy-based glues. In case the substitute does not contain hazardous substances, there is no toxic impact, see scenarios 3 and 4. However, from the point of view of the company producing the plywood, technical innovation for new glue is resource demanding, and legal pressure is not encouraging to initiate such substitution currently.

Nevertheless, from the company's point of view, legal developments are alerting and call for considering further improvements long term in order to lower emissions.

The use of the information verification scheme highlighted the need for a more frequent updating of information from suppliers (out-dated classification of formaldehyde and phenol). It also identified a potential problem area in the future, since the IARC classification of formaldehyde is stronger, than the EU classification, which might lead to changes in product-related standards. The application of the method helped to identify a direction for improvements and also for potential legislative changes in the future, giving companies a head start in preparing for future standards and providing justification for investing in innovation regarding resin.

3.3. APPLICATION OF THE LIFE CYCLE ASSESSMENT TO COMPARE THE ECODESIGN PROPOSALS GENERATED

The aim of the life cycle assessment study was to generate ecodesign proposals to reduce toxic impacts and increase material efficiency. The functional unit of one traffic sign is chosen to which all environmental impacts are attributed. The system borders include extraction of raw materials, processing of materials, and ends with waste management options (see Fig. 9 and 10).

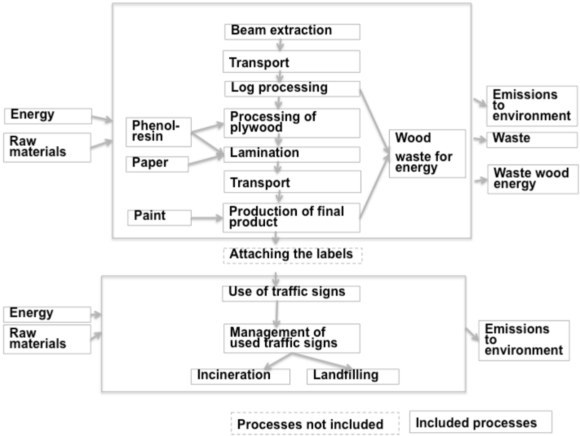


Fig 9. The system borders of the life cycle assessment for traffic sign from plywood

A life cycle model for both products was built using SimaPro software. The data were obtained from producers of plywood and tin traffic signs in Latvia, and supplemented with life cycle inventory data from the SimaPro 7.2.2 library.

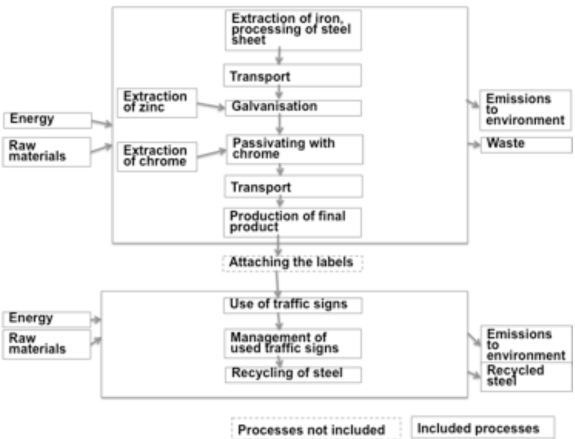


Fig.10. The system borders of the life cycle assessment for traffic sign from tin

Two life cycle impact assessment methods were applied: Ecoindicators'99 and EDIP -2003. As seen from the results, the both methods delivers opposite conclusion, if using a single score indicator, see Fig. 10. These differences can be explained by the different normalisation and weighting approaches highlighting the need for good understanding of the life cycle methodology in order to be able to interpret results.

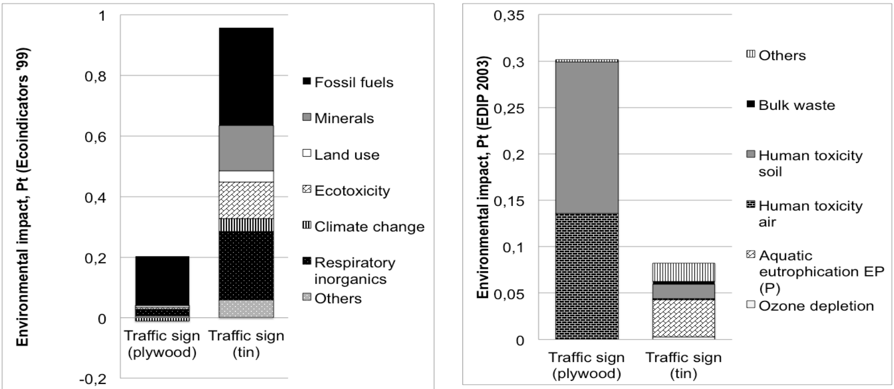


Fig 11. The environmental impact of plywood and tin signs expressed through a single score indicator

In order to generate ecodesign proposals, the contribution analysis was performed in order to single out the most influencing phases of life cycle with regard to material use and toxic impacts. The generated proposals are summarised in Table 5.

Table 5

Ecodesign proposals regarding traffic sign from tin and plywood

Material	Problem	Proposals
Plywood	High impact of phenol-resin and its raw materials on causing toxic impacts	Phase out use of phenol-resin The intelligent choice of suppliers (according to the environmental product declarations)
	Emissions of formaldehyde during use of the product	Reduce concentration of formaldehyde in the phenol-resin (co-operate with the supplier)
	High impact of phenol-resin and its raw materials on resources	Phase out use of phenol-resin The intelligent choice of suppliers (according to the environmental product declarations)
Tin	High impact of use of galvanisation to toxicity and resources	Find a replacement for zinc coating, of reduce thickness of zinc coating
	High impact of steel extraction and processing on toxicity to human health, environment, resources	Recycling and reuse of traffic signs
	High impact of electricity production	The intelligent choice of suppliers (according to the environmental product declarations)

PART 4. DISCUSSION

In this chapter the findings of the whole research are discussed and compared with the findings of other researches reported in literature.

Many ecodesign tools address the toxic impacts of substances present in materials and products by applying characterization factors of life cycle impact assessment. Some other tools use a chemicals classification system, thus covering a larger share of the potential hazardous substances. The new ecodesign method developed within this study revises the existing ranking of the hazardous properties of chemicals, based on the chemicals classification according to the GHS. The scientific novelty of this method is adding the ranking of exposure of consumers and environment by releases of chemical substances from products leading to a more comprehensive evaluation of potential toxic impacts.

The application of the developed eco-design method for plywood products has identified the same important aspects of the use of plywood which is highlighted by Werner and Richter, 2005, on the LCA studies related to timber products: the high consumption of fossil resources for the production of plywood associated with synthetic resin. However, Werner and Richter [46] do not mention the impact on the health of the consumer from the formaldehyde releases of timber products. Consumer health and indoor environment is not usually evaluated in life cycle assessment projects, which is the opposite approach taken by the method developed hereto.

According to the taxonomy of Bovea and Pérez-Belis [47] an eco-design tool has to correspond to three criteria: early integration of environmental aspects, life cycle approach, multicriteria approach. With regard to the method proposed hereto, it is possible to apply the method in the early design stages, with a precondition, that the chemicals and materials applied are known or predicted and that the supply chain communication on their hazardous properties starts already at the product design phase. The method currently focuses on two life cycle phases: use of the product and end of the life cycle. Nevertheless, mitigating hazardous chemicals in the products to a large extent also means mitigating the same substances in the whole supply chain e.g. the production is indirectly addressed as well. The approach applied hereto allows integration of other environmental aspects e.g. embodied energy, carbon footprint, depending on needs, following the same methodology.

Luttropp and Johansson [34] propose to improve material efficiency by tagging the relevant information to the product. Chemicals reduction can also be achieved by promoting more accurate chemical records in the material declarations e.g. at least indicating all additives >0,1% mass corresponding to REACH criteria of substances for very high concern although not yet included as candidates for substsnces of very high concern (SVHC). Such an approach would eliminate the barrier for reducing toxics impacts through ecodesign indicated by Braungart et al., 2007 [11], since the application of the method can lead to an improvement in the information flow via the supply chain on toxic additives in the products and materials.

The product information of wood preservatives studied hereto did not meet the requirements of the legislation, which is consistent with the findings of other researchers on the quality of the information supply chain. Work demonstrated that a company willing to reduce the adverse effects of chemicals, needs knowledge and a system to collect and verify the information from suppliers, in order to avoid misinterpretation of the chemical hazards, see Figure 11.

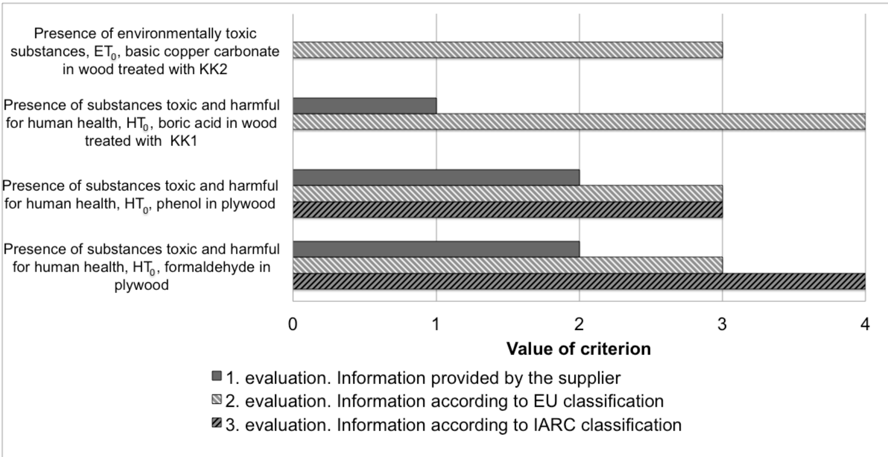


Fig. 11. The criteria values depending of source of information on chemicals classification

The growing market for products sounder to the environment and health is encouraging the introduction of voluntary ecodesign measures, which exceed the legislative requirements. Starting with a preference for organic food, the sales of other environmentally sound products is also increasing, despite the fact that some of these products may be more expensive [50]. More probably, recent developments can be explained by an increased value of health in the eyes of consumers and better knowledge on the consequences to health of products used, as only purely by environmental awareness. In some product groups, consumers are ready to purchase products with higher environmental performance even if they are 50% more expensive [50]. This trend indicates an increasing market opportunity for products sound to human health and the environment, and the costs invested in eco-design can pay off. Following this trend, world-leading companies are declaring a phase out of hazardous chemicals within their supply chain. The application of the method presented in this article would help to implement such a supply chain policy.

Regarded as the most progressive chemicals law in the world, the REACH regulation mainly addresses the application of chemicals that have to be assessed before they are put on the market. The regulation requires that hazard and risk assessment information is passed down the supply chain via safety data sheets. For products, however, such information is required in exceptional cases only and delivered upon request, e.g. if the product contains SVHC or candidate >0,1%. Nowadays, due to market globalisation, many materials and products are produced outside the EU and are imported into the EU, and this tendency is increasing. In opposite to chemicals, there is no requirement to assess the chemicals compositions of products before importing them into the EU except for some strictly regulated chemicals and toys. The ecodesign method developed within this study can support companies to obtain more confidence on the chemicals safety of imported products by improving hazard communication within the supply chain. Although missing legislative requirements on standards for material declarations can be seen as a constraint for the use of this method, the experience with the implementation of the RoHS directive and also ecolabelling proves that such communication in the supply chain is possible. The approach proposed hereto would also promote the consumer's right to know the environmental and health impacts caused by the products they purchase.

The usage of the method also depends on whether or not the method delivers information relevant for consumers to explain the value added to the products. The simulation by Bleda and Valenta [52] shows that only customers provided with appropriate information on the environmental preference of products will choose them. The elaborated method does not deliver a single score indicator, but improves life cycle inventory data. By applying this method, a company can claim an introduction of a supply chain management system to phase out hazardous substances with cancerogen, mutagen, and reprotoxic properties from their products.

CONCLUSIONS

The research introduced within this thesis contributes to the elimination of adverse impacts of chemicals related to the leaching of hazardous substances from the products during their use and at the end of life.

A new semi-quantitative ecodesign method applicable for different types of products has been developed. The application of the new ecodesign method includes the ranking of the most severe chemical hazards by using chemicals classification according to Globaly Harmonised System of Classificatino of Chemicals, combined with exposure ranking following the principles of chemicals risk assessment. The application of the method is demonstrated with few case studies on different products. The method allows the eco-designer to identify needs for and elaborate ecodesign proposals, and promotes communication and information exchange through the supply chain.

In order to identify and assess the hazardousness of chemical substances, the method applies the GHS classification of chemicals that currently offers a larger coverage of undesired impacts compared to the frequently used characterisation factors of the life cycle impact assessment methods.

The pilot studies demonstrated the importance for verification of information provided by suppliers to avoid the misleading interpretation of the real hazards due to lack of knowledge. In the information verification there is a need for a tiered approach, and biotesting with *D.magna* can be a relatively simple way to alert hazards.

The usage of the method promotes an advanced supply chain management and hazard communication. As a minimum, the information on substances falling under the REACH criteria for substances of very high concern shall be available in the supply chain, although REACH currently requests this only for substances selected as SVCH candidates by the authorisation process. As demonstrated with the case study, a systematic approach in the verification of information received from suppliers is an important aspect in the management of materials.

REFERENCES (MENTIONED IN SUMMARY)

1 **Human health risk assessment toolkit: chemical hazards**, IPCS project on the Harmonization of Approaches to the Assessment of Risk from Exposure to Chemicals, WHO, 2010, p.88.
2 **Binetti at al, 2008, Binetti R. et al,** Exponential growth of new chemicals and evolution of information relevant to risk control, 2008, Ann Ist Super Sanita, 44 (1), p. 13-15
3 **Allanou R. et al.,** Public availability of data on EU high production volume chemicals - Part 2, *CHIMICA OGGI (Chemistry today)*, July-August, p. 59-64
4 **Irigaray P. et al.,** Lifestyle-related factors and environmental agents causing cancer: an overview, *Biomedicine & Pharmacotherapy,* 2007, 61 (10), p. 640-658
5 **Hwang H.M. et al.,** Occurrence of endocrine-disrupting chemicals in indoor dust, *Science of The Total Environment,* 2008, 404 (1), p. 26–35
6 **Fridén U.E. et al.,** Chlorinated paraffins in indoor air and dust: Concentrations, congener patterns, and human exposure, 2011, *Environment International,* 6. p.
7 **Fuglei E. et al.,** Environmental contaminants in arctic foxes (Alopex lagopus) in Svalbard: Relationships with feeding ecology and body condition, Environmental Pollution, Issue 146, 2007, p. 128-138
8 **Vorkamp K., et al.,** Levels and trends of persistent organic pollutants in ringed seals (Phoca hispida) from Central West Greenland, with particular focus on polybrominated diphenyl ethers (PBDEs), 2008. *Environment International,* 34 (4), p. 499-508
9 **HELCOM, 2011,** Helsinku Komisija, Baltijas jūras stāvoklis, Bīstamās vielas, [tiešsaiste] [skatīts 14.04.2011]. Pieejams: http://www.helcom.fi
10 **Meadows D.H. et al,** Limits to Growth: The 30-Year Update, Chelsea Green Publishing Company, White River Junction, Vermont, 2004, p.325
11 **Braungart M. et al.,** Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design, 2007, *J. of Cleaner Production,* 15 (13-14), p. 1337-1348
12 **Niederl-Schmidinger A., Narodoslawsky M.,** Life Cycle Assessment as an engineer's tool?, 2008, *J. of Cleaner Production*, 16, p. 245- 252
13 **GHS,** Globally Harmonized System of classification and labelling of chemicals, United Nations, New York and Geneva, 2000, p.431, GHS - ķīmisko vielu klasificēšanas un marķēšanas globāli harmonizētā sistēma, [tiešsaiste] [skatīts 24.01.2011]. Pieejams: http://www.unece.org
14 **ISO 14040:2006,** Environmental management - Life cycle assessment -Principles and framework , Geneva, Switzerland: International Organisation for Standartisation, 2006
15 **Technical Guidance Document** in support of Commission Directive 93/67/EEC on Risk Assessment Part I, EC, Joint Research Centre, EUR 20418 EN/2, Printed in Italy, 2003, p. 311; [tiešsaiste] [skatīts 30.01.2011]. Pieejams: http://ecb.jrc.ec.europa.eu
16 **Karlsson R., Luttropp C.,** EcoDesign: what's happening? An overview of the subject area of EcoDesign and of the papers in this special issue, *J. of Cleaner Production,* Volume 14, Issues 15-16, 2006, p. 1291-1298
17 **Adu I.K.,** et al., Comparison of methods for assessing environmental, health and safety (EHS) hazards in early phases of chemical process design, 2008, *Process Safety and Environmental Protection,* 86 (2), p. 77-93
18 **Knight. P, Jenkins J.O.,** Adopting and applying eco-design techniques: a practitioners perspective, 2009, *J. of Cleaner Production*, 17 (5), p. 549-558
19 **ECMA 341,** Ekodizaina integrācija produktu izstrādē, ECMA-rūpniecības asociācija (Informācijas un saziņas tehnoloģija, elektronika patērētājiem) (Information and Communication Technology, Consumer Electronics), [tiešsaiste] [skatīts 14.03.2010]. Pieejams: http://www.ecma-international.org/publications/standards/Standard.htm

20 **The Oeko-Tex Standards**, [online] [accessed 10.02.2012]. Accessible: http://www.oeko-tex.com
21 **BASTA,** IVL Swedish Environmental Research Institute & the Swedish Construction Federation, [online] [accessed 14.09.2011]. Accessible: http://www.bastaonline.se
22 **Nissen N.F.,** Entwicklung eines ökologischen Bewertungsmodells zur Beurteilung elektronischer Systeme, Doctoral Dissertation, Technical University of Berlin, Department of Electrical Engineering, 2001, p. 202
23 **Wenzel H. et al.,** *Environmental Assessment of Products,* Volume 1: Methodology, Tools and Case Studies in Product Development, 1997, p. 564
24 **Lithner D. et al,** Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition, 2011, *Science of the Total Environment,* 409 (10), p. 3309-3324
25 **Ahrens A**. et al., G*uidance for the use of environmentally sound substances, For producers and Professional users of chemical products relevant to the aquatic environment*, *Part one, Five steps for the evaluation of environmental risks*, Publisher: Federal Environmental Agency (Umweltbundesamt), Germany, 2003, p. 66
26 **ECOIT**, [tiešsaiste] [skatīts 14.04.2011]. Pieejams: PRé Consultants, http://www.pre.nl/content/about-pre
27 **Idemat**, Delft Tehniskā universitāte, [tiešsaiste] [skatīts 14.04.2011]. Pieejams: http://www.idemat.nl/
28 **Huang H. et al.,** Materials selection for environmentally conscious design via a proposed life cycle environmental performance index, 2009, *The International J. of Advanced Manufacturing Technology,* 44 (11-12), p. 1073-1082
29 **Rosenbaum R.K., et al.,** USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment, 2008. Int. J. of Life Cycle Assessment, 2008, 13 (7), p. 532-546
30 **Meijer A. et al.,** Human Health Damages due to Indoor Sources of Organic Compounds and Radioactivity in Life Cycle Impact Assessment of Dwellings Part 1: Characterisation Factors, 2005. *Int. J. of Life Cycle Assessment,* 10 (5), 2005, p. 309 – 316
31 **Cho K.T.**, Multicriteria decision methods: an attempt to evaluate and unify, 2003, *Mathematical and Computer Modelling,* 37, 2003, p. 1099-1119
32 **Harmonized classification and labeling of certain hazardous substances**, Annex VI, table 3.2 of regulation REACH, EC No 1272/2008 (online) (accessed 15.04.2011). Accessible: http://ecb.jrc.ec.europa.eu/esis/index.php?PGM=cla
33 **EK Nr. 1907/2006,** EPP Regula (2006. gada 18. XII), kas attiecas uz ķimikāliju reģistrēšanu, vērtēšanu, licencēšanu un ierobežošanu (REACH) (OV L 396/1-850, 30.12.2006.)
34 **Johansson J., Luttropp C.,** Material hygiene: improving recycling of WEEE demonstrated on dishwashers, 2009, *J. of Cleaner Production,* 17 (1), p. 26-35
35 **Iakovoua E. et al.,** A methodological framework for end-of-life management of electronic products, 2009, *Resources, Conservation and Recycling,* 53 (6), p. 329–339
36 **Cerdan C. et al.,** Proposal for new quantitative eco-design indicators: a first case study, 2009, *J. of Cleaner Production,* 17 (18), p. 1638–1643
37 **Mathieux F. et al,** ReSICLED: a new recovery-conscious design method for complex products based on a multicriteria assessment of the recoverability, 2008, *J. of Cleaner Production,* 16 (3), p. 277-298
38 **Otto K.N., Wood K.L.,** ***Product*** *Design, Techniques in Reverse Engineering and New Product Development,* Prentice Hall, 2001, p.1061

39 **Guinee J.B. (**ed), *Life cycle assessment-an operational guide to the ISO standards*, 2002. Centre of Environmental Sciences (CML), Leiden University, Kluwer Academic Publishers, 692
40 **IARC** Monographs on the evaluation of Carcinogenic Risks to Humans, The International Agency for Research on Cancer (IARC), [online] [accessed 11.07.2011]. Accessible: http://monographs.iarc.fr/ENG/Monographs/PDFs/index.php
41 **Everitt, B.S.,** *Cambridge Dictionary of Statistics*, West Nyack, NY, USA: Cambridge University Press, 2002. p 300.
42 **LVS EN ISO 17294-2:2005**, Ūdens kvalitāte - Induktīvi saistītās plazmas (ICP-MS) masspektrometrijas lietošana - 2.daļa: 62 elementu noteikšana, LVS/STK/25 Vides kvalitāte
43 **SimaPro 7.2.2.,** datorprogramma, © PRé Consultants, Nīderlande
44 **Fammler H. at al.,** "Ķimikāliju riska pārvaldība uzņēmumos", „Managing Chemicals Risks in Enterprises", Rokasgrāmata profesionālajiem ķimikāliju lietotājiem, "Jelgavas Tipogrāfija", ISBN Nr: 9984-9679-9-9, Latvija, 2003
45 **Michna J. et al.,** Management of energy and environment conservation: current methodical problems, 2011, Latvian J. of Physics and Technical Sciences, 1 p.28-41, Doi: 10.2478/v10047-011-0003-z
46 **Werner F., Richter K.,** A Literature Review, Wooden Building Products in Comparative LCA, 2005, *International J. of Life Cycle Assessment*, 10 (5), 2005, p. 309 – 316
47 **Bovea M.D., Pérez-Belis V.,** A taxonomy of eco-design tools for integrating environmental requirements into the product design process, 2011. *J. of Cleaner Production*, In Press, Corrected Proof, Available online 23 July 2011
48 „**European Classification and Labelling Inspections of Preparations**, including Safety Data Sheets", Final report, 64 pages, [tiešsaiste] [skatīts 03.07.2011]. Pieejams: http://hesa.etui-rehs.org
49 **Hinks J. et al.,** Views on chemical safety information and influences on chemical disposal behaviour in the UK, 2009, *Science of the Total Environment,* 407, p. 1299–1306
50 **Green Retail Trends in Europe 2010**, Research Report, Prepared by Centre for Retail Research. Nottingham, pp. 39
51 **Enforcement Guidance document**, Version 1, May 2006, developed through discussions within the „EU RoHS Enforcement Authorities Informal Network", p. 16, [tiešsaiste] [skatīts 20.02.2011]. Pieejams: http://www.bis.gov.uk
52 **Bleda, M., Valente, M.** Graded eco-labels: a demand-oriented approach to limit pollution, 2009. *Technol. Forecasting and Social Change*, 76 (4), 512-524

Jana SIMANOVSKA

AN ECODESIGN METHOD TO REDUCE ADVERSE EFFECTS OF CHEMICALS DURING PRODUCT LIFE CYCLE

Summary of thesis

Copies: 90
Printed and bound "Elpa-2" Ltd. Gutenbergs druka, Mūku ielā 6, Rīga, LV-1050
2012