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Improvement of Environmental Performance of Publishing Processes: Application of the Integrated Criteria

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This article is focused on printing industry, environmental impact assessment of the prevailing environmental issues, use of resources, waste production and possible options to solve environmental problems. Printing industry is "difficult" due to product diversity and differences of their parameters. A systematic evaluation is essential to analyse impact on the environment and to identify opportunities for implementation of the eco-label the Nordic Swan. The research is based on data from one of experimental Lithuanian design and printing company.

To assess the life cycle of printing process, the software SimaPro 8 has been used. 1 ton of printing products was chosen as the functional unit for the impact assessment. The assessment included 1 ton of different paper sorts. The assessment of the offset printing process of the pilot company was conducted in accordance with the criterions of a group P of the eco-label the Nordic Swan (version 5.4). The layout software of green graphic design was used as an additional preventive tool for reduction of the environmental impact.

The assessment of the life cycle of printing processes revealed that the process of offset printing have the most significant impact on the environment in all the categories of impact. The analysis of paper materials revealed that recycled paper has the least impact on the environment. The total impact does not exceed 5% when compared to all other tested materials. Chalk coated printing paper made from mechanical pulp has the biggest impact. The assessment of the company's activity in accordance with the criterions of the group P of the eco-label the Nordic Swan showed that tested company had 63,6 points (122 points is the maximum). To reduce identified environmental problems in the Lithuanian printing industry and to meet the requirements of the Nordic Swan, environmental performance improvement recommendations have been developed. The recommendations are applicable in any company in this branch of industry.

Keywords: *eco-labeling, LCA, paper flow, printed matter, printing industry*

1. Introduction

Currently, the European and Lithuanian printing industry faces serious economic troubles, because the increased role of Internet in providing information and advertisement, e.g. number of newspapers and magazines decreased significantly (Kibirskis, 2012). Over the past 10 years, the added value of the volume of publishing printed materials decreased by 65% in Lithuanian; the number of the companies in this branch of industry decreased by 57,1% (similar tendencies are observed in other EU countries) (SD, 2014), (Eurostat, 2014). In the last years, a small growth of this sector is observed; the extent of manufacturing has increased by 14,2% comparing to 2011 and export increased by 13,0% in 2012 (SD, 2014), (Gendre, 2010). Denmark, Norway, Finland and Sweden are the countries with the biggest production potential. These countries apply very strict criterions of the product entrance into the market, which are based on the quality of the company's activity, competitive price and the assessment of printing products' life cycle as well as reduction of the impact on the environment (Izgorodin, 2013).

Publishing and printing industry is a sector that uses big amount of natural resources. Paper, cardboard, paint, adhesives, printing plates are the main materials used in the printing and publishing industry (Kinderyte, 2011), (Enroth, 2001). The biggest amount of natural resources is used during the

manufacturing process of paper. Manufacturing of non-standard products has very significant impact, because big amounts of paper waste are generated during the manufacturing process. According to statistic data, the annual decline of the amount of paper waste in the European Union is equal to 20%. Lithuania has tremendous opportunities for paper and cardboard recycling. The annual potential of recycling of the Lithuanian cardboard factories is approximately 40 thousand tons of paper and cardboard waste. However, only 25% of this amount is collected in Lithuania, the remaining part is imported. 14% of all municipal waste in the country is paper and cardboard (SD, 2014). Change of environmental awareness is not the only priority, it also important to induce the companies that act in the sector of publishing to implement voluntary environmental initiatives and measures such as eco-design of the products and their eco-labeling. The latter is based on the assessment of product life cycle and impact on the environment "from the cradle to the grave".

The assessment of life cycle is recognised as the most widely and the most effectively used measure to reduce impact on the environment from the printing processes and products. (Rafenberg, 1998), (Larsen, 2009), (Kariniemi, 2010).

Eco-design of printing products is also recognised as one of the measures for manufacturing of environment friendly products. The eco-design of 1 ton of the products that was performed in the Danish company that is involved in sheet offset printing revealed that use of chemicals is the most significant environmental aspect. Use of chemicals during the printing process is equal to 41% of all impact on the environment, use of ink corresponds to 18% and cleaning corresponds to 17% of all impact on the environment. Approximately 18% of paper and 33% of energy are used during the manufacturing process of printing products (Larsen, 2009).

Cleaner production measures are increasingly used to solve the problems that arise in the publishing and printing sector. At the same time, ISO 14001, ISO 9001 and EMAS standards are being introduced in companies. However, use of the life cycle, the assessment of eco-label criterions (such as the Nordic Swan) and preventive measures of green design haven't ever been explored extensively in Lithuanian companies.

The main objective of this research was identification of environmental problems that dominate in the Lithuanian industry of printing and analysis of the potential systematic methods to solve environmental and economic problems. The research was based on the data from the company that is involved in the activity of printing.

2. Methods

2.1. The methodology of life cycle assessment of printing products

The methodology of life cycle assessment based on ISO 14040 – 14043 standards was used in the research (Staniškis, 2005). The assessment of life cycle is an excellent measure applicable for the environmental assessment of materials, processes and products within the determined boundaries (Bousquin, 2011).

On the basis of ISO standard, the following phases of life cycle assessment have been identified:

1. The description of the purpose and extent; the determination of the functional unit of the research and the system boundaries.
2. Inventory analysis; determination of the material balance in the printing processes and energy flows.
3. Impact assessment and interpretation.

1. The main purpose was to determine the most significant categories of the impact on the environment and to ensure the optimal use of the resources.

   The boundaries of the research were selected on the basis of the most commonly used stages of the printing products' manufacturing and the main materials used in each stage. (Figure 1). Different paper sorts have been selected in the databases of software ecoinvent 3 to analyse environmental impact of the main manufacturing component, i.e. paper material.

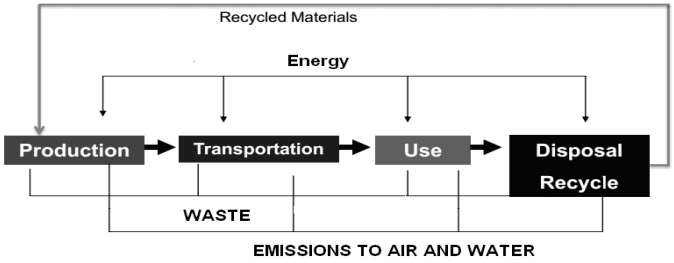

Fig. 1. LCA system boundaries for printing products (Venditti R.A., 2012)

To assess the processes, a functional unit was selected. In this case, 1 ton of various printing products that are manufactured using the leaf offset printing machine Heidelberg Speedmaster CD 102+5+L has been selected. On the basis of the rules of product categories, the same functional unit of raw paper material, i.e. 1 ton of raw material, must be considered. The system boundaries: between extraction of raw materials

and use of these materials in the manufacturing processes.
Functional unit was selected on the basis of the research that was accomplished by other scientists (Vercalsteren, 2011), (Larsen, 2009).

2. In the research, the data collected in the company during 2013 was used. The data was used to develop material balance in printing process and to analyse energy flows.
3. For the life cycle assessment, SimaPro 8 software and the methodology EDIP 2003 (Environmental Design of Industrial Products) was used for environmental impact assessment (Larsen, 2009). This is the Danish methodology of life cycle assessment that that can be used as an alternative for the methodology EDIP 97. The selected methodology enables assessment of 18 categories of the impact on the environment.

2.2. The assessment of the criterions of the eco-label the Nordic Swan

The system of the eco-label the Nordic Swan is based on the life cycle assessment and the assessment of the company's printing process in accordance with the determined criterions of eco-label, i.e. general criterions and the ones based on points (Figure 2).

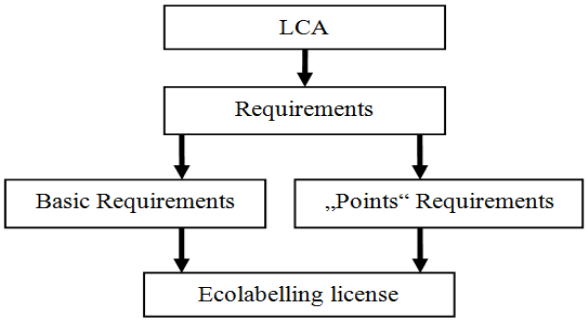

Fig. 2. The basis for the eco-labeling (Kariniemi, 2010)

The assessed criterions are divided into three groups: O + figure, P + figure and M + figure.

The criterions of the group O are mandatory, P – mandatory criterions, based on point calculation. The criterions of the group M are mandatory after completion of the licensing process. The criterions of the eco-label „Version 5.4“ have been used. This version is valid between the 15th of May 2011 and the 31st of December 2017 (Nordic Ecolabelling, 2014).

The assessment of the offset printing process of the experimental company was conducted in accordance to the criterions of the group P. At least 63 points are necessary to implement the eco-label.

2.3. The auxiliary tool for optimisation of paper flows

The software of green graphic design – layout is used as an auxiliary tool to ensure optimisation of paper flows and to assess the impact on the environment. Reduction of the waste that is generated during manufacturing process and reduction of the product's impact on the environment are the main objectives. This software is also recognised as an excellent economic tool that enables cost reduction since lower quantity of paper is needed to manufacture the products. The calculator is based on the standards of harmony, which are not certified, but recognised as the logic collection of criterions. The groups of standards are intended for raw materials, design, recycling and the production itself.

In the assessment, the following 8 parameters have been selected: the method of printing, the paper class, the size of a list of paper, the weight of a list of paper, the size of finish, margins in accordance to the device settings, the print edition, and the number of pages in the product. All calculations have been conducted using the bio-energetic program developed by non-profit environmental protection agency based in California. Additionally, the calculator created by the Environmental Protection Fund and other databases of various products have been used.

3. Results and discussion

3.1. The life cycle assessment of printing processes

The results of the assessment presented in Figure 3. Analysis of manufacturing processes' impact on the environment during the whole life cycle revealed the fact that the offset printing process and the materials used during this process generate the major impact on the environment in all the categories of the impact (from 20% to 97%). The major impacts of offset printing are distributed as follows: soil toxicity for agriculture due to human activities - 97 % (due to the primal product manufactured), chronic eco-toxicity in the soil – 94 % (due to the primal product manufactured) and use of natural resources – 87% (aluminium waste and paper). The printing process is the main stage of printing product manufacturing and the largest amounts of materials are consumed during this stage (Figure 3).

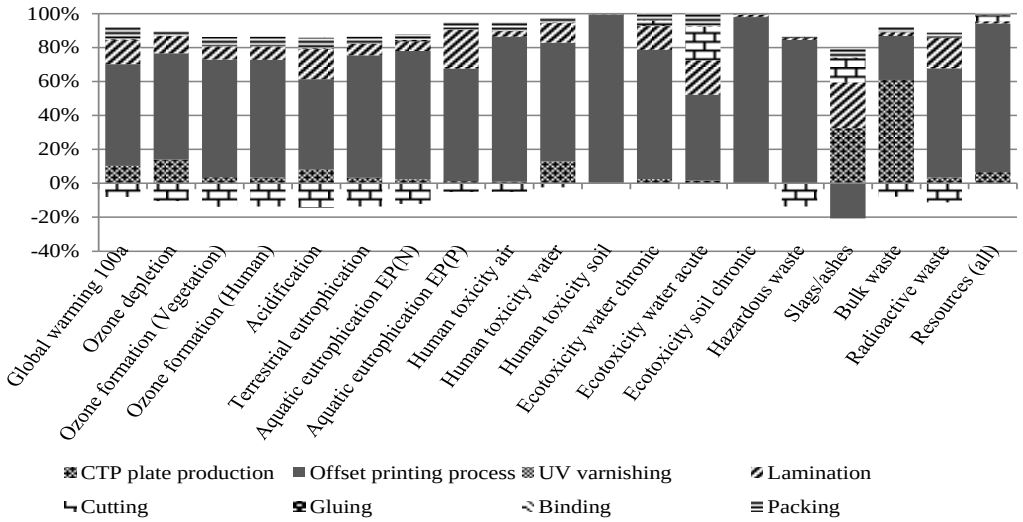

Fig. 3. The distribution of 1 ton of various printing products impact on the environment in accordance with the processes of manufacturing and the categories of the impact on the environment, %

The wider analysis of materials concerning their impact on soil toxicity and eco-toxicity revealed that the primary product manufactured during the process of offset printing, i.e. the product of printing (e.g. brochure, flyer, catalogue) have the biggest impact due to the fact that the printing products' life duration is very short (approximately 1 year) and majority of these products are disposed in the landfills.

Aluminium waste (~ 65 %) and consumption of paper (~25 %) mostly influence the excess use of natural resources. Currently, there are no alternatives for substitution of these materials.

Different sorts of raw materials have been selected for analysis: cardboard, 100% recycled paper, chalk coated printing paper made from mechanical pulp (mechanical mass), chalk coated printing paper made from mechanical pulp (chemical mass), and uncoated paper. (Figure 4).

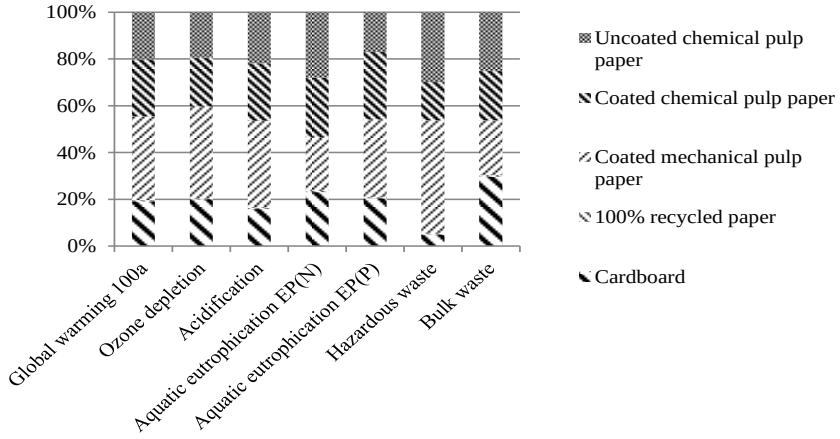

Fig. 4. The assessment of 1 ton of different sorts of raw paper materials on the environment, %

The biggest impact is equated to 100%, whereas other percentages are distributed in accordance to the reference point. The results of the analysis revealed that fully recycled paper in all 7 impact categories has the least impact on the environment. The impact of the recycled paper in all categories when compared to other raw materials does not exceed the impact of other raw materials by 5%. The chalk coated printing paper made from mechanical pulp (mechanical mass) has the biggest impact on the environment. The diagram reveals the fact that cardboard raw material has the biggest impact on the formation of solid waste – 159,76 kg per 1 ton. The cardboard impact on the environment in many areas of impact is very similar to the impact of the uncoated paper.

3.2. The results of the assessment of the Nordic swan criterions

The assessment of Lithuanian publishing and design company in accordance with the P group criterions of the Nordic Swan revealed that the company partly meets the requirements to obtain the environmental label. The sum of the points calculated after completion of the assessment was 0,6 higher than the minimum sum of points, i.e. 63 points (maximum sum of points is 122). The biggest loss of points is due to paper, use of chemicals and volatile organic compounds.

Analysis of the quality and accuracy of the assessment revealed that reliability of the data is 80%. The overall conclusion was made that the company is

not prepared yet for the implementation of the eco-label the Nordic Swan.

3.3. The results of green graphical-layout research

Re – nourish calculator is a preventive tool to reduce paper waste. To obtain the results, a written survey of 20 companies has been conducted and 27 parameters of products have been collected. The distributions of the surveyed companies: 20% - micro companies, 30% - small companies, 10% - medium-sized companies, and 40% - large companies. To perform a comprehensive determination of the impact on the environment, each product was assessed in the software as a separate project. Software supported the assessment of impact in terms of energy consumption, water demand for manufacturing, hard particle generated in manufacturing, emissions and timber demand in the production.

The format of printing pages is selected in accordance to the standards. The impact on the environment depends on the selected product format, because this influences the amount of paper waste that is generated in manufacturing. Moreover, the higher number of paper lists is in the product, the more paper and timber resources is required.

The parameters of 17 different sorts of advertising printing products collected in the survey were different. 74% of the chalk coated printing paper made from mechanical pulp, 14,7% of offset paper and up to 12% of other type of paper is used in manufacturing process. The paper of higher weight/ thickness is characterised by higher durability and less susceptible to wear/ tear. The printing paper made from mechanical pulp has a good durability; however the chalk covered paper has significantly bigger impact on the environment in comparison to uncoated paper. The offset method is applied for the printing of 81,5% of the products, digital-offset method is used for the printing of other products. One sided printing is used in production of packaging, labels, leaflets or flyers. These products have the lowest service life and turn into a waste quickly. The analysis revealed that limited use of recycled paper is considered to be a problem. Only 3,7% of 27 different advertising printing products are printed on the recycled paper due to lack of environmental awareness and cost saving (currently, the price of the recycled paper is 1,5 times more expensive than ordinary chalk coated paper.

Summarised results of the impact on the environment and possible reduction of the impact after adjustment of the layout is presented in the Table 1.

Table 1. Products' impact on the environment and possible reduction after adjustment of the layout

Products	Minimising the amount of paper required for the product, %	Reduction the number of trees required for the product, %	Environmental impact reduction %	Product layout minimisation, %
Insurance brochures	34.33	27.25	27.69	12.5
Leaflets	12.20	12.14	12.31	4.7
Books	33.33	66.55	66.64	10.2
Sewn brochures	55.56	55.54	55.81	15
Flyers	42.92	42.92	42.95	18
Gadgets (sewn brochures)	33.33	33.33	35.33	26.4
Package	17.46	17.46	17.40	-
Catalogues (sewn listed on brochures)	55.56	55.56	55.89	15
Catalogues (saddle-stitched brochures)	55.54	55.54	56.57	15
Labels	54.67	50	51.22	10.2
Price cards	19.40	11.08	11.06	-
Flyers	33.61	35.16	35.17	2.1
Catalogues (saddle-stitched brochures)	33.66	33.66	35.22	13.3
Price lists	10.45	9.60	13.22	1.5
Books	16.68	16.68	16.88	21.1
Educational materials	55.56	55.56	55.57	15
Educational materials	55.56	55.56	56.70	13.6
Catalogues (made of aluminum-covered booklet)	33.33	33.33	33.34	15.5

In cases when format reduction is impossible due to the product's functionality, more convenient format of printing list of paper has to be selected. Since the majority of advertising printing products are promotional or informational, reduction of the product format does not strongly influence the product functionality. Reduction of product format could lead to significantly decreased impact on the environment (from 11% to 66%.

4. Recommendations for optimization of paper and chemicals flows in the companies

Results of the life cycle assessment in terms of one functional unit revealed that the process of offset printing and use of paper/ chemicals have the biggest impact on the environment. Assessment of P group criterions of the Nordic Swan indicated the same significant aspects. To reduce the company's impact on the environment and to fulfil the requirements of

eco-labelling, recommendations for paper and chemicals management have been developed.

4.1. Recommendations for optimisation of paper flows

Assessment revealed a number of opportunities to reduce impact on the environment, but it requires changes in the product and there is a danger that product functionality could be altered. Therefore, each case should be analysed separately by taking different parameters into account. To reduce impact on the environment from the advertising printing products, general layout rules divided in accordance to different parameters should be considered.

Results of the analysis and possible evaluation criterions enabled development of an assessment algorithm. This algorithm can be used in assessment of impact on the environment from various types of advertising printing products and in identification of possible measures to reduce the impact. The algorithm with an example is presented in the Figure 5.

Sample print product
Brochure

Paper
Coated wood-free paper
Environmental impact

Impact category	Unit	Coated wood-free paper	Cardboard
Global warming 100a	kg CO2 eq.	1,101	0,043
Ozone depletion	kg CFC11 eq.	$0,81*10^{-7}$	$0,387*10^{-8}$
Acidification	m^2	0,1051	0,0041
Aquatic eutrophication EP(N)	kg N	0,0007	$0,387*10^{-4}$
Aquatic eutrophication EP(P)	kg P	0,0006	$0,305*10^{-4}$
Hazardous waste	kg	0,000107	$0,17*10^{-4}$
Bulk waste	kg	0,104	0,006

Paper grammage reduction
Now product is printed on 130g/m^2 , substitutable to 100g/m^2
Environmental impact

Impact category	Unit	130 g/m^2	100 g/m^2	Savings
Global warming 100a	kg CO_2 eq.	1,53	1,177	0,353
Ozone depletion	kg CFC11 eq.	$1,3671*10^{-7}$	$1,05*10^{-8}$	$1,262*10^{-7}$
Acidification	kg SO_2 eq.	0,0077	0,0059	0,001775
Eutrophication	kg PO_4^{3-}	0,0033	0,0025	0,00076

Layout selection
Environmental impact

Layout percentage reduction	%	10
Bulk waste	kg/unit	5,98
Paper cost savings	EUR/mintage	493

Font size and type selection
25% decrease in the amount of paint needed

Impact category	Unit	16g. Ink	12g. Ink	Savings
Global warming 100a	kg CO_2 eq	0,0552	0,0414	0,0138
Ozone depletion	kg CFC11 eq.	$3,66*10^{-9}$	$2,74*10^{-9}$	$9,16*10^{-10}$
Acidification	kg SO_2 eq.	$2,24*10^{-4}$	$1,68*10^{-4}$	$5,6*10^{-5}$
Eutrophication	kg PO_4^{3-}	$1, 35*10^{-4}$	$1,01*10^{-4}$	$3,372*10^{-5}$

Soft cover 10g/product
Hard cover 50g/product

Fig. 5. The algorithm for assessment of advertising printing products applicable for the optimisation of paper flows

To preserve the product functionality and to keep its properties unchanged, a systematic assessment should be conducted.

4.2. Recommendations for optimisation of the flows of chemical substances

Analysis revealed that the biggest environmental impact is associated with use of mineral oil based paints, washing fluid V60, isopropyl alcohol (IPA), and volatile organic compounds (VOC). To reduce emissions of chemical VOC compounds, use of environmentally more friendly paints and washing agents is suggested. Such chemicals can be easily recycled and are not harmful to humans and the environment (Carstensen, 1997), (Hattori, 2008).

The calculations revealed that the main environmental loss for the company is related to VOC emissions. This influences economic and environmental benefits of the company. Substitution of currently used chemical substances based on mineral oils by the materials of vegetable origin can lead to reduction of the impact on the environment by 90,7%. The material acquisition costs may decrease by 9,9%, and the lost costs associated with VOC and waste management may decrease by 78,7%.

In case when all suggested measures for material substitution would be implemented, the sum of the points collected for the eco-label would be 87,06 (VOC emissions would be equal to 1,47 kg/t of production, the sum of the appointive points is 17,06; the use of the paints of vegetable origin provides additional 12 points).

The assessment of the Nordic Swan is long and expensive procedure. It is very difficult to assess what financial benefit can the Nordic Swan provide for the company, but experience of other companies and the data of the Nordic Council of Ministers suggests that the total sales could increase by up to 20% (the Nordic Council of Ministers, 2014). For example, Latvian printing-house LivoniaPrint has acquired the Nordic Swan eco-label in 2012. In 2011 the annual sales of the company were equal to 25 million EUR. In 2013, the sales have increased to 31,0 million EUR, i.e. by 19,4% (Bluma J., 2013), (LIAA, 2013).

5. Conclusions

1. The life cycle assessment of printing processes was conducted using the software SimaPro 8 and the methodology of the impact on the environment EDIP 2003. LCA functional unit was determined - 1 ton of various printing products printed by offset printing technology and 1 ton of paper material. The assessment of impact on the environment of the selected functional units revealed that materials, which are used in the offset printing processes have the biggest impact on the environment in all stages of LCA and in all categories of impact. The biggest impacts in the printing process are distributed as follows: soil toxicity for agriculture due to human activities - 97 % (due to the primal product manufactured), chronic eco-toxicity of the soil – 94 % (due to the primal product manufactured) and use of natural resources – 87% (aluminium waste and paper). The assessment of paper life cycle revealed that fully recycled paper has the lowest impact on the environment in all categories of impact. The chalk covered printing paper made from mechanical pulp (mechanical mass) has the biggest impact on the environment.
2. The assessment of the company's offset printing process in accordance to the criterions of the Nordic Swan P group (5.4 version) revealed that the tested company has collected 63,6 points of total 122 points to be collected. The biggest loss of points is associated with the use of paper and chemical substances as well as VOC emissions.
3. The analysis of 18 products was conducted by green graphical design software layout. The reduction of product format was applied for majority of the products. Smaller formats of the products enabled to achieve the reduction of the impact on the environment from 11% to 66%. The annual savings could be from several thousands to more than 49 000 EUR per year.
4. To reduce the impact on the environment and to meet the requirements of the Nordic Swan criterions, several recommendations to solve the problems have been developed. To reduce impact on the environment from the paper waste, the algorithm for experimental printing product was created.
5. Recommendations for the management of chemical substances are based on the substitution principle, i.e. use of environmentally more friendly chemical substances. Substitution of currently used chemical substances based on mineral oils by the materials of vegetable origin can lead to reduction of the impact on the environment by 90,7%. The material acquisition costs may decrease by 9,9%, and the lost costs associated with VOC and waste management may decrease by 78,7%. The total sum of the points collected for the eco-label the Nordic Swan would be 87,06.

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Leidybos procesų aplinkosauginio veiksmingumo didinimas: integruotų kriterijų taikymas

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Šiame straipsnyje nagrinėjamas poligrafijos pramonės bei jos daromo poveikio aplinkai vertinimas, pramonės šakoje vyraujančios problemos, išteklių naudojimas, gamyboje susidarančių atliekų kiekiai ir jų tvarkymas bei galimi problemų sprendimo būdai. Ši pramonės šaka yra sudėtinga dėl gaminių įvairumo, jų parametrų skirtingumo. Atsižvelgus į pastaruoju metu poligrafijos pramonėje kylančias problemas, šiame straipsnyje analizuojamos poligrafijos pramonės poveikio aplinkai vertinimo priemonės, pramonės šakoje vyraujančios problemos susijusios su išteklių naudojimu, gamyboje susidarančių atliekų kiekiais ir jų tvarkymu bei „Šiaurės gulbės“ aplinkosauginio ženklo diegimo galimybės. Tyrimas atliekamas naudojant eksperimentinės Lietuvos dizaino ir leidybos įmonės duomenis.

Spaudos procesų, būvio ciklo įvertinimui atlikti buvo naudojama SimaPro 8 programinė įranga. Analizuojamas funkcinis vienetas spaudos procesų poveikiui įvertinti - 1 tona įvairių spaudos gaminių gaminamų ofsetine lapine spaudos mašina. Skirtingų popieriaus rūšių poveikiui įvertinti, funkcinis vienetas - 1 tona žaliavų. Tiriamos įmonės ofsetinės spaudos proceso ekoženklo vertinimas buvo atliekamas pagal „Šiaurės gulbės“ P grupės kriterijus (5.4 versiją). Kaip papildoma poveikio aplinkai mažinimo priemonė naudojama „žaliojo“ grafinio dizaino – maketavimo programinė įranga.

Spaudos procesų būvio ciklo įvertinimo metu nustatyta, jog ofsetinės spaudos procesas daro didžiausią įtaką aplinkai visose poveikio kategorijose. Popieriaus žaliavų tyrimo analizė parodė, kad mažiausią poveikį aplinkai daro 100 % perdirbtas popierius. Suminis poveikis neviršija 5 % nuo visų kitų vertintų žaliavų. Didžiausias poveikis nustatytas kreidinio mechaninės masės popieriaus. Įvertinus įmonės veiklą pagal „Šiaurės gulbės“ P grupės kriterijus tiriamoji įmonė surinko 63,6 taškus iš 122 galimų.

Siekiant sumažinti nustatytas Lietuvos poligrafijos pramonės aplinkosaugos problemas ir nustatyti būdus, kaip atitikti keliamus „Šiaurės gulbės“ reikalavimus, buvo pateiktos visoms šios pramonės šakos įmonėms pritaikomos rekomendacijos.