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Original scientific paper

Life Cycle of Aluminium Packaging

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Abstract: Aim is to analyze environmental load with aluminium packaging, used in food industry. especially with aluminium cans. LCA shows origin of materials, aluminium production, as basic materials, emission to air, water and soil and quantitz of wasting materials, as a result of production of 1000 aluminium cans.

This study includes:

- raw material for aluminium production
- aluminium production
- aluminium cans production
- usage and recycling of aluminium cans.

For this study we gathered data for fuel and energy consumption, amount of raw materials, products and byproducts, emission to air, water and soil, and a quantity of waste material. Within a metode of calculation of influences to environment as indicators was used:

global warming (kg $CO_{2\text{-ekv.}}$), eutrophication (kg $P_{\text{-ekv}}$), acidification (kg $SO_{2\text{-ekv.}}$), ekotoksicity (kg 1,4 DB-$_{\text{ekv.}}$), reserves shortage of nonrenewable resources (kg), water consumption (kg), toksicity for humans (kg 1,4 DB-$_{\text{ekv.}}$), oyone layer destruction (kg $R11_{\text{-ekv.}}$) soil occupation (m^{2} god.). LCA model is made by GaBi 4 software system (verzion GaBi 4.3) [8].

In order to have relevant estimation of influence to environment, we defined cut-off proces value. In this case as cut-off value was used value of weight ratio less than 5%, and in that case proces disregarded.

Key words: Life Cycle Assessment LCA, aluminium beverage cans

INTRODUCTION

Packaging is indispensable for food products. Food is packaging with different purpose and in different packaging materials. Nowdays we have a lot of different materials for packaging. Packaging has numbered basic functins as well some specific functions. Basic usage is protection, ability to transport, and trade. Beside of basic functions, packaging should be economicaly and environmentaly justified. This packaging functions comes from different characteristic of materials used.

Through time packaging changed, packaging functions improved changed become more complex, from realy basic usage protection against deterioration to very sofisticated functions were gaseous and water steam passes packaging to active packaging with absorbers or emitters, or inteligent packaging communicating with environment. Packaging is necessary, and needful, but have influence on environment. Thats why it is important that packaging development and packaging materials improves environmentaly characteristic, to have less negative impacts to environment.[1, 2].

Aiming to estimate impact of packaging to environment we are conducting packaging life cycle analysis. Lyfe cycle analysis (LCA) is a tool seting up framework for influence analysis any product or process to environment. LCA represents series of inter conected phases, from raw materials to finaly waste. This cycle studies influences through lyfe cycle to environment, air, watercourses and soil. From ekologic point of view, development of packaging materials and packaging, represents activity aiming to decrease a volume of packaging waste, finding solutions for reuse, recycling, incineration or volume decrease for easier postponement to garbage dump. Aim for usage of LCA is to optimize materials, save water and energy consumption, decrease garbage volume and maximize reuse with recycling processes or combustion [2].

Within this study, we followed LCA of aluminium cans. In the first place we focused on aluminium as raw material, and aluminium cans. It was estimated influence to environment, starting from raw materials, processing, recycling and postponement of aluminium packaging. Reason for this study is widely used metal (aluminium) packaging for packing food and drinks, especially because of good protecting characteristics this materials poses.

Aluminium is light silvery white metal extracted from bauxite. Aluminium makes excelent barrier against humid, air, odours, light and microorganisms, also with good elasticity and flexibility, great extensibility and shape modeling, godd heat conductor. With all of this advantages Aluminuim makes extremelly value as material for recycling, whit ability for several recycling cycles, with no changes of performances and negative impact on environment [1, 4].

MATERIALS AND METHODS

To estimate influence to lyfe cycle of aluminium packaging was used GaBi 4 method, and some parts also used with ReCiPe 1.08 method to colect and processing of data, such as estimate of toxicity on humans and ecosystems. For example in category of „global warming“ influence influence from gasous with efect of greenhouse effect (CO_2, CH_4, N_2O, itd.) presents as summ, through equivivalent influence of reference substances, in this case as ReCiPe method CO_2. Indicators on final positions sometimes called as damage indicators, because it is used for mesaurment of damage as result of gasous emissions and usage of natural resources in the life time of named product [3, 8].

Toxicity for humans is summ of lost years of life causing premature life looses and summ of lost years of healthy persons, because of health impact from polluted environment. For this purpose we use DALY *(Disability Adjusted Life Year).*

Ecosystem variety damage is measured with biodiversity loss in some areas, and volume of damage is expresed in number of species lost in certain time period as result of environment pollution or soil usage. It is expressed as „no species x years.

Damage for decreasing of mineral resources availability is evaluate based on estimated growth of marginal costs for exploitation of mineral resources to environment: future and efect of cost raise on global economy costs. It is expressed US$ [13].

Results of this analysis (LCA) contains data on species and quantity of natural resources, quantity of basic raw materials and quantity of emissions during production of 1000 aluminium , as final result of investment. Tabels 1 and 2 showed inputs and outputs for aluminium production from bauxite. Tabel 3 shows that for 1000 aluminium cans we need approximatelly 17 kg of al layers, produced from aluminium ingots, and needfull quantity of energy and materials water emissions, air and soil emissions, and quantity of waste.

Total amount of elementary flow *i* (*Ei*) in life cycle of metal packaging cycle is expressed with equation :

$$E_i = \sum_{j=1}^{n} I_j E_{i,j}$$

where: *Ij* – input *j* life cycle of methal packaging, *Ei,j* – ammount of elementary flow *i* life cycle of input *j* and n – number (types) different inputs in to life cycle of aluminium packaging [13].

Tabel 1. Inputs and outputs for production of 1000 kg raw aluminium [10]

INPUTS	UNIT	QTY
Bauxite	kg	5246,2
Natrium-hydroksid (50%-sol)	kg	172
Calcijm-oxid (Mineral)	kg	75,5
Diesel fuel	kg	1,31
Electric power	MJ	865,6
Heat energy from coal	MJ	3060,2
Heat energy from oil fuel	MJ	7851,7
Heat energy from natural gas	MJ	7909,6
Water	kg	15190,0
OUTPUTS		
Aluminium-oksid (alumina)	kg	1915,4
Danger waste: grase	kg	0,91
Red sludge (dry)	kg	2187,0
Industry waste	kg	29,3
Solid waste	kg	47,1
Sand (Al processing)	kg	58,3
Air emissions: dust	kg	4989,7
mercury fume	kg	4,02E-04
Water emissions: Suspended solids	kg	0,091
surface water	kg	10160,5

Tabel 2. Inputs and outputs for bauxite for 1000 kg Al raw material [10]

INPUTS	UNIT	QTY
Diesel fuel	kg	6,0436
Electric power	MJ	36,21
Heat energy (oil fuel)	MJ	52,89
Heat energy (natural gas)	MJ	0,07
Bauxite (non-renewable resource)	kg	5775,8
Water surface	kg	2633,7
OUTPUTS		
Bauxite	kg	5246,2
Dust (Air particules)	kg	5,1
Stock suplies	kg	529,6
Fumes	kg	143,6
Surface water (emissions to air)	kg	2514,9

Tabels 1 and 2 shows that for production of 1000 kg of aluminium, we need approximately 5776 kg bauxite from non renewable resources, which is later processing getting approximately 5246 kg bauxite for producing alumine. Of5246 kg processed bauxite is obtained approximately 1915,4 alumine. Of 1915,4 kg alumine we can produce approximately 1000 kg aluminium, over 99% purity, and in that form we use it for producing and modeling cans.

Tabel 3. Qty of Al foil for 1000 Al cans

INPUTS	UNIT	QTY
Energy and fuel		
Energy	MJ	77,62
Heat energy (natural gas)	MJ	70,37
Heat energy (fuel oil)	MJ	0,6
Metals		
Aluminium foil	kg	16,78

Other materijals		
Water	kg	85,77
Coating for cans	kg	0,916
H-fluorid	kg	0,225
Sulfuric acid aq. (96 %-tni)	kg	0,198
Lime, Ca-oxid (cubes)	g	77,2
Oil lubricated	g	39,42
Paints for cans	g	31,25
Poliethilen (PE)	g	13,61
Polypropylene (PP)	g	17,87
Solvent	g	8,781
OUTPUTS		
Product: Cans	no.	1000,0
Emisija u vazduh		
Alcohol (unspec.)	g	43,77
Ethylenglycol	g	23,9
Ether (unspec.)	g	4,03
Formaldehyde (methanol)	g	2,02
Oil	g	0,987
Xylene (dimethyl benzene)	g	2,36E-2
Mg^{2+}	g	1,13E-2
H-fluorid	g	9,21E-3
Ethyblenzen	g	6,23E-4
Methanol	g	2,47E-4
Emissions to water		
Effluent	kg	58,63
Phosphorus	kg	0,5
Dissolved materials	kg	0,11
Sulphatates	kg	0,045
chemical oxygen demand (COD)	kg	0,026
Ca^{2+}	kg	0,02
biochemical oxygen demand (BOD)	g	3,9
Chloride	g	3,5
Suspended solids	g	3,5
Total org binded C	g	2,4
Na^{+}	g	2,1
Oil (unspecified)	g	1,4
Total Nitrogen	g	0,89
Fluoride	g	0,45
Al^{3+}	g	0,43
Kalium	g	0,3
Mg^{3+}	kg	1,4E-4
Silicates particles	kg	7,6E-5
As^{5+}	kg	3,0E-5
Stroncium	kg	1,4E-5
Mn^{2+}	kg	9,2E-6
Fenili (hydroxy benzene)	kg	8,3E-6
Sulfides	kg	5,2E-6
Iron	kg	3,3E-6
Zn^{2+}	kg	3,0E
Selen	kg	2,9E-6
Cu^{2+}	kg	2,6E-6
Barium	kg	1,3E-6
Cl	kg	1,2E-6
Pb^{2+}	kg	9,1E-7
Chrom (unspecified)	kg	9,0E-7

Cd^{2+}	kg	8,6E-7
Cianides	kg	5,2E-7
Ni^{2+}	kg	3,5E-7
Ag	kg	2,9E-7
Hg^{2+}	kg	1,1E-8
Other waste		
Aluminium remains	kg	3,447
Total waste for incineration	kg	0,225
Sludge	kg	0,174
Waste (recycling)	kg	0,13
Waste from incineration	g	49,66
Waste (landfill)	g	44,03
Sludge(processing)	g	26,31
Danger waste for incineration	g	0,752

RESULTS AND DISCUSSION

Scoring results of influnce of life cycle of aluminium cans expressed within the results of indicators levels by specific cathegory. Review of results of indicators is showed in table 4. It is visible from the results which categories and the level of influence are responsible for influence of life cycle of aluminium cans to environmen.

Tabel 4. Rezults evaluation of influences of life cycle of 1000 Al limenki in percentage (%)

Influence category	Production of raw materials	Production of final product	Distribution	Usage	Waste
Decreasing of non renewable resources	45,5	0	25,1	10,0	25,0
Global warming	0,79	0,20	0,8	0,05	98,0
Acidification	27,5	0,05	18,16	3,0	51,3
Ozone layer destruction	2,0	0,12	2,7	3,1	92,0
Ekotoksicity	19,0	0,2	7,4	8,0	65,4
Human toxicity	17,4	0,05	8,0	0,05	75,0
Occupying soli	15,0	1,0	0	0,3	83,7
Eutrof. water	1,0	0,03	0,5	0,87	97,6

The biggest part in reduction of non renewable resources comes to pahese of production of raw materials app 45,5 %, and after that comes phase of distribution with 25,1 % and deposit phase app 25,0 %. As global warming category biggest influence makes deposit phase app. 98,0 %. In process of acidification biggest influence comes from deposit phase with 51 %, and after comes production of raw materials and phase of distribution. app. 27,5 i 18,2 %. Deposit phase has biggest influence to other categories: toxicity on humans with 75,0 %, ozone layer destruction with 92,0 %, occupying soil with 83,7 %, ekotoksicity with 65,5 % i eutrofikationof water with 97,6 %.

It is obvius analyzing tabel 4 that phase of deposit of used cans has the biggest influence to environment.

CONCLUSIONS

Based on fact that one aluminium can can remain in environment for 500 years [1], taking into account that the process of recycling of aluminium cans almoast without impact on environment, and that colected cans are payed on collecting points, we should pay more atention to this issue. Besides that, aluminium is metal obtained from bauxite a non renewable resource, also used in other industries not just in food industry. Globaly we have pozitive trend of recycling of aluminium cans, but in Bosnia and Herzegovina still not the pozitive trend.

LCA analysis of aluminium cans as modern tool is more and more use in industry to minimize emissions of dangerous materials in to air, water and soil and to protect environment. Resource management through recycling policy considerably influence to save energy and protect environment, reduce the price on packaging material market and decresaing the pollution of environment by reducing the ammount of solid waste .

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Conflict of Interest

Authors declare no conflict of interest.

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