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ECOLOGICAL AND ECONOMICAL ASPECTS OF USE OF BIO-LUBRICANTS AND CONVENTIONAL LUBRICANTS

Abstract

It is believed that more than 50 % of produced lubricants during or/and after the operation is due directly or indirectly to the environment. For these reasons, in areas where the application of lubricant is related to the total "loss" in the environment, there is a tendency to replace conventional oil with bio-lubricants, environmentally acceptable lubricants. From an environmental point of view, the advantages of using vegetable oil as compared to conventional mineral oils are non-toxicity, bio-degradability, renewability, good lubricity, high flash point and viscosity index, low volatility, savings and conservation of non-renewable resources, less dependence on non-renewable resources, reduced emissions of greenhouse gases and increased agricultural production. From an economic point of view, the price of biolubricants is higher compared to conventional lubricants since in production of biolubricants as a base are used vegetable oils (triglycerides) or synthetic fatty acid esters and therefore, the list of components or additives is significantly limited. Accordingly, in this paper we define the "ecological footprint" of a liter of conventional mineral oil compared with one liter of biolubricant for the lubrication of chainsaws, since this lubricant is used in highly-sensitive application areas, complex forest ecosystem. The aim of this paper is to present the "pure life cycle" through Life Cycle Assessment (LCA) for both types of lubricants and environmental parameters expressed in economic terms to encourage reflection on the further development of this sector, while also raising awareness of end-users.

Key words: *biolubricants, ecological footprint, Life Cycle Assessment (LCA), Environmental Life Cycle Costing (ELCC)*

Introduction

The growing concern for the environment led to certain changes in the world of lubricants. The increasingly stringent environmental regulations have led to the development of lubricants which are fulyl or partially biodegradable and do not show toxic effects in the environment.

Unlike conventional lubricants, which are based on mineral base oils, biolubricants are based on oils of vegetable origin, synthetic esters or polyglycols. Table 1 shows the production of biolubricants in Europe in 2008 as well as forecasts for 2020.

Table 1. European production of biolubricants in 2008 and forecasts for 2020

European production of biolubricants in 2008 and forecasts for 2020				
	Production 2008		Production forecasts for 2020	
Industrial applications	Total production of lubricants (t)	Production of biolubricants (t)	with moderate incentive policy	with strong incentive policy
Hydraulic fluids	650 000	68 000	155 000	230 000
Lubricants for chainsaws	50 000	29 000	37 000	40 000
Mould release oils	100 000	9 000	15 000	30 000
Other uses*	3 600 000	31 000	70 000	120 000
Total	4 400 000	137 000	277 000	420 000
Source: European Renewable and Materials Association, EU-Public/Private Innovation Partnership "Building the Bio Economy by 2020" as part of "Innovation Union-A flagship initiative within the Europe 2020 strategy".				

Principles and framework for life cycle assessment (LCA) consider: definition of the goal and scope of the LCA analysis of the elements of the life cycle (LCI), the impact assessment phase of the life cycle (LCIA), the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, refers between the LCA phases, and conditions for the use of electoral values and optional element. The study covers the life cycle assessment (LCA) and elements of the life cycle (LCI), usually does not describe the LCA technique in detail, nor determine methodologies for the individual phases of the LCA.

The application of LCA or LCI results could be taken into account when defining the objectives and scope, but the application itself is beyond the scope of this International Standard. Accordingly, in Figure 1 are presented the phases of LCA (Life Cycle Assessment)

LCA is carried out in four phases: i) determining the goal, SCOPE, ii) inventory lifecycle, iii) assessing the impact of the life cycle and iv) the interpretation of the results. However, in order to calculate the true ecological and economic value of the use of bio- or conventional lubricants, it is necessary to calculate the LCA for each element that is used in the formulation of the finished product.

Practically, this means that it is necessary to calculate the LCA of base oil and additives in each particular formulation. Only then we can get closer to the real value, both from an environmental and an economic standpoint. Figure 2. shows simplified 'way' of production bio- and convential lubricants as well main difference in production system.

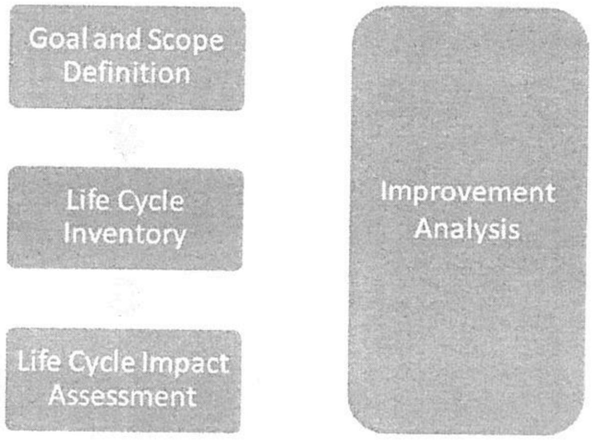

Figure 1: LCA (Life Cycle Assessment) of bio- and conventional lubricants

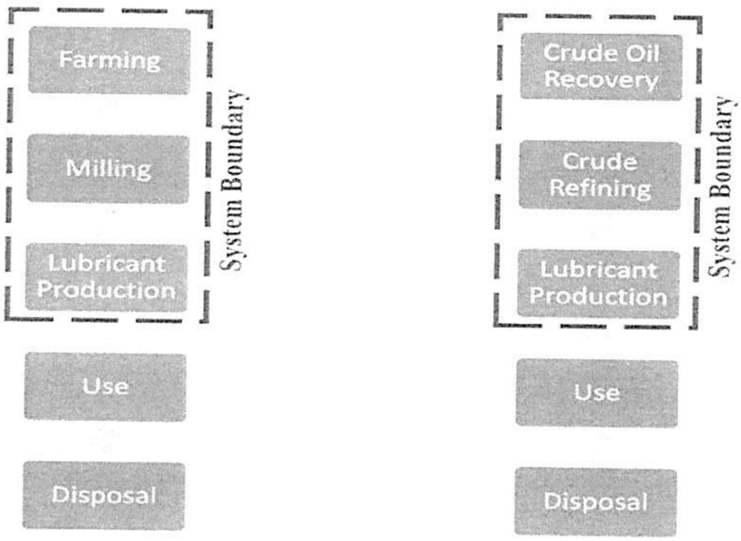

Figure 2: LCA (Life Cycle Assessment) phases (source: Baumann and Tillman, 2004)

As it shown in Figure 2, the main life cycle stages of a biolubricant include farming, milling, refining, use and disposal. For traditional lubricants the life cycle stages include crude oil recovery, crude refining, lubricant refining, use and disposal. Figure 3 shows simplified flowcharts of the life cycle stages for rapeseed and soybean biolubricants, and for production of mineral based lubricants. The GHG and CAP inventory for rapeseed lubricants varies significantly from the mineral lubricant inventory.

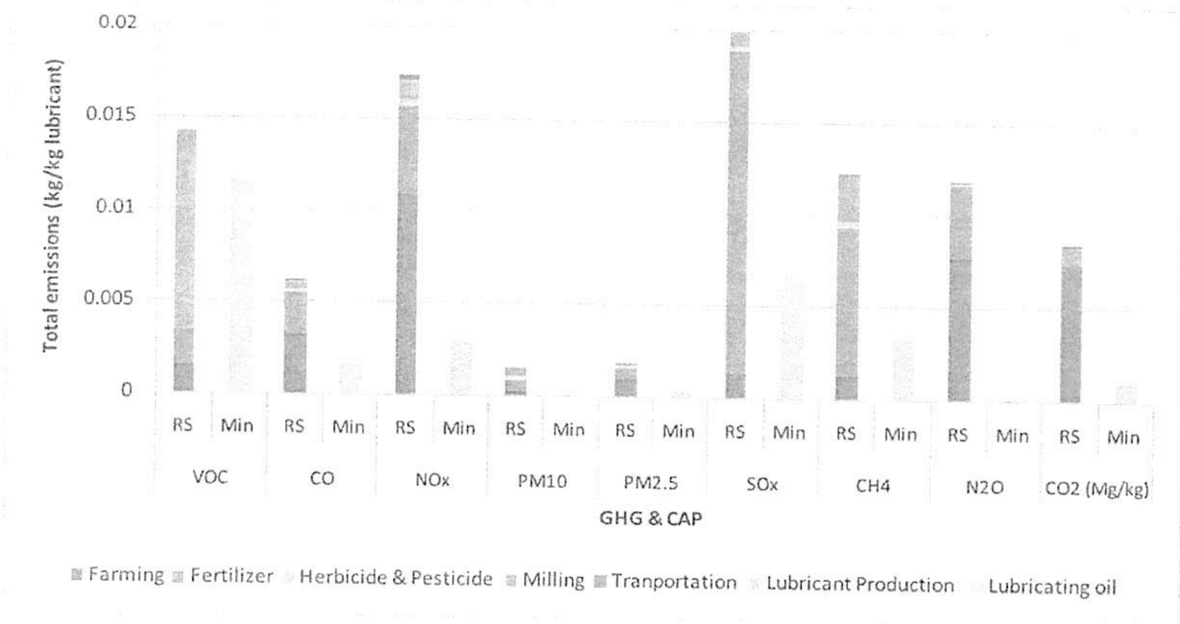

Figure 3: Flowcharts of the LCS for biolubricants and mineral based lubricants; „RS“ refers to rapeseed oil, „Min“ to mineral oils.

Figure 4 shows the negative/side effects of different oils on the environment such as global warming, acidification etc. On the y axis is presented quantitative approximate value of side effects.

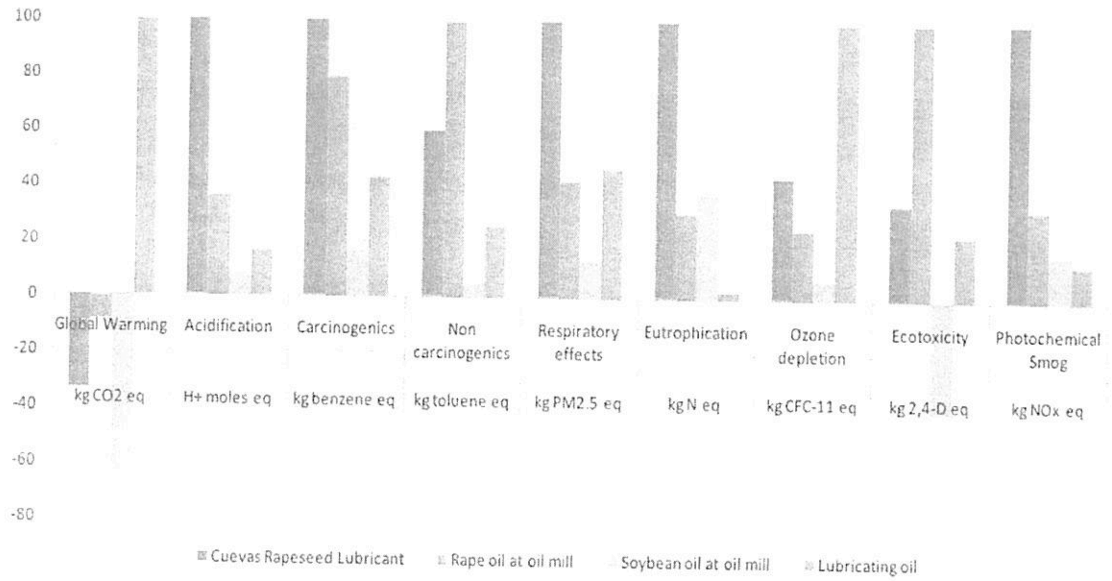

Figure 4: Normalized LCIA results (source: Cuevas and Phoebe, 2010)

LCA results showed that the oil based on the rapeseed oil shows a tendency to eutrophication and potentially the production of photochemical smog while mineral lubricants dominate in the potential global warming and ozone depletion. However, it should be noted that the LCA analysis has certain restrictions that could change the outcome as seen with inventory. This means that it requires additional calculations in order to obtain more precise results.

Life cycle costing (LCC) of bio- and conventional lubricants

The main problem of increasing consumption of bio-oils is their price, which is roughly 10 to 20 % higher than that of conventional lubricants. Establishing consistent metrics, which would provide comparable results, would bring benefits for all stakeholders and consequently to enviroment. This would contribute to establishing the conditions that the analysis of the ecological footprint becomes a universally accepted metric by governments, which would be used parallel with the financial indicators, as an indicator for the development planning and decision-making. Businesses pioneers who introduce a new environmental technology equipment and materials for production would have substantial economic benefits in the form of a lower purchase price. Individuals would be given the option to choose the product or service neutral to the environment and be aware of their impact on nature.

Formulated structure of conventional oil for chainsaws:

- 2 - 4 % EP additive
- 0.5 – 1 % Corrosion Inhibitor
- 0.3 - 0.5 % Antioxidant
- The base fluid up to 100%

Formulated structure of bio-oil for for sawchains:

- 2 % EP additives
- 1 % Antioxidant
- 0.4 % Corrosion inhibitor
- 1.5 – 2 % Thickening agent
- 1 -5 % Adhesion additive
- Vegetable oil up to 100%

If we compare the formulation of bio- and conventional lubricants for saw chain lubricating, we notice that in the formulation of bio-lubricants additives that are toxic are used, but in a certain dosage or degree that doesn't influence a total formulation to have a negative cumulative effect of the finished product on the environment.

From the point of application, there are certain limitations in the use of bio-lubricants, which are primarily:

- oxidation stability, results of a shorter time interval changes, which implies a higher consumption compared with those of conventional lubricants;
- narrow interval the operating temperature;
- the instability at the higher temperatures (above + 80 ° C);
- poor low temperature properties (can not be used at temperatures below - 20 ° C).

A simplified scheme of Life Cycle Costing (LCC):

Capital
+
Lifetime operating costs
+
Lifetime maintenance
+
Disposal costs
–
Residual value

} LCC

However, the above chart does not give a complete picture of total costs, so it is needed to expand it in order to reach the true costs and justify the higher cost of environmentally friendly lubricants. This can be achieved by including environmental externalities in the LCC. In this way, it can stimulate and direct the market to the greater ratio of consumption of bio oil. Market education is meant as an initial step towards a larger share of bio-oils in the total consumption of lubricants. Figure 5 practically present an economic analysis of environmental life cycle costs and the real environmental costs.

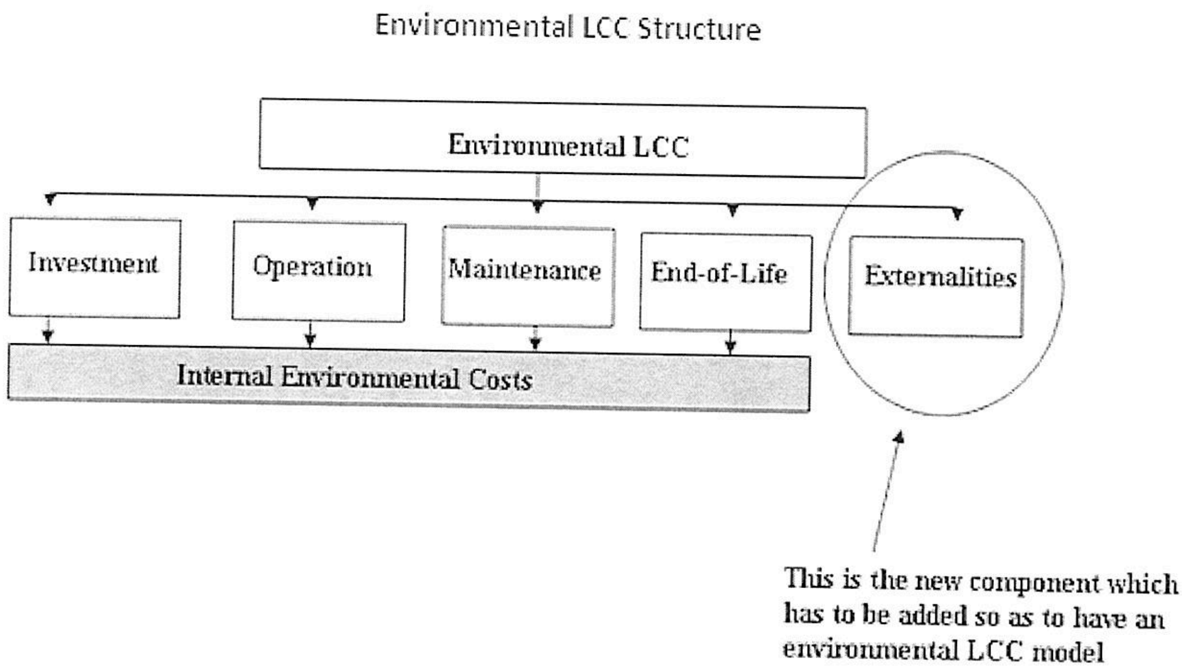

Figure 5: A simplified scheme of Environmental Life Cycle Costing (ELCC)

Review of basic environmental impact LCA and (E)LCC

Production of 1 MT of refined rapeseed requires about 6 kg seed plantations and at least 1 ha. Just several processes causing 90 % of the total negative impact in the production process of saw chain bio lubricants. Impacts are related to the use of mineral fertilizers in the production of rapeseed that are responsible for 47 % of the total negative impact, use , while emissions of N_2O and NH_3 from land arising by volatilization and denitrification of nitrogen from ammonia-nitrate fertilizers cause 32 % of the negative impact. The occupation of land in the agricultural phase is responsible for 38 % of the negative enviromental impacts. Looking at the individual elementary streams "occupying farmland" causes about half of the impact in the life cycle until air emissions are responsible for about 37 %. Figure 6 shows the relationship between biocapacity of our planet and the total ecological footprint.

According to the Living Planet Report 2010, Global Footprint Network, currently we require nearly 1.5 planets to support the annual needs of humankind. The report also states that „Analysis of global biocapacity reveals that more that 50 % of global biocapacity is within the borders of the 10 countries". In the recent years, due to environmental protection requirements, the use of biodegradable lubricants is often required. There is difference between terms "biodegradable" and "rapidly bio-degradable". Illustrated in Figure 7 is the difference in degradation timing of a readily biodegradable product compared to an inherently biodegradable product.

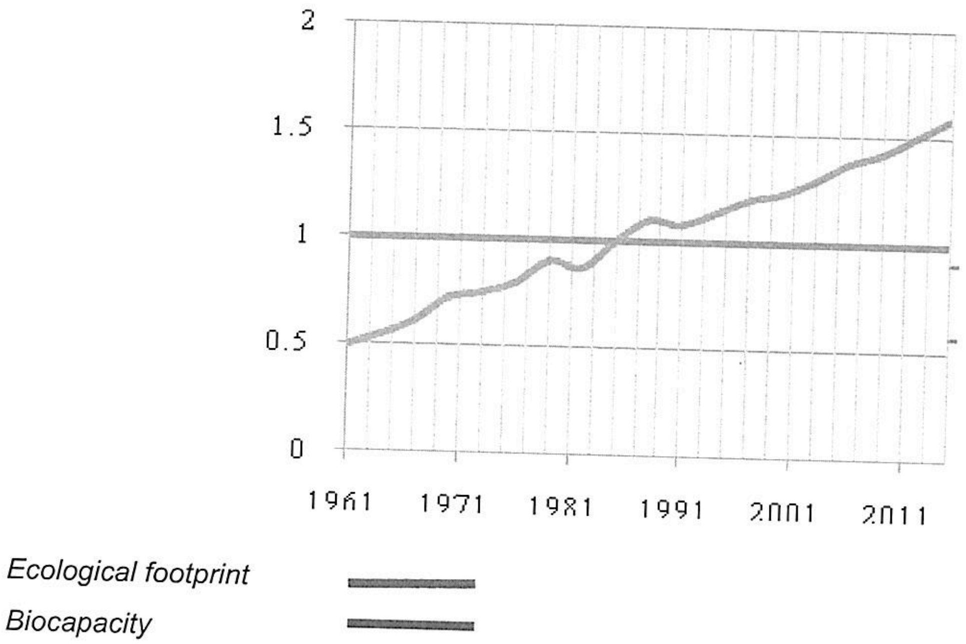

Figure 6: The relationship between biocapacity and ecological footprint expressed in PE (Planet equivalents, y-axsis)

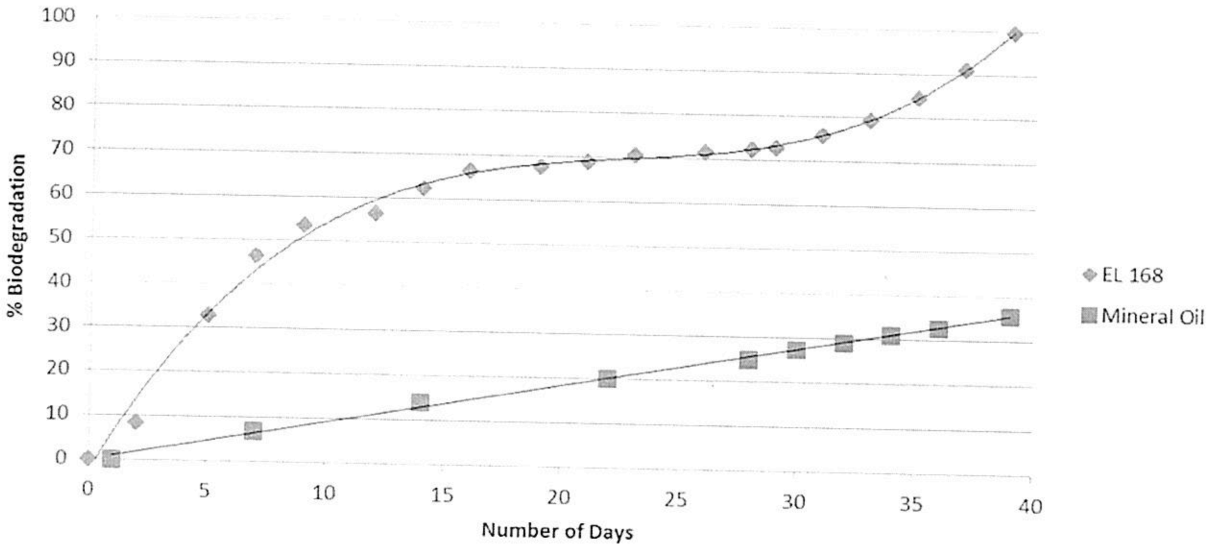

Figure 7: Ready Biodegradation
Source: Roell, C.B., Miller, M. 2013.New EPA Regulations Governing Environmentally Acceptable Lubricants. RSC Bio Solutions.

It is easy to see the difference between a readily biodegradable vegetable based product and an inherently biodegradable mineral based product. The EPA and Coast Guard utilize this differentiation when evaluating an oil release.

The decomposing process carried out by microorganisms which are transformed in the ideal case the oil to carbon dioxide, water and the protein. Mineral oils produced from crude oil are biologically hardly degradable. Degradation can take months or even years. Lubricants, whose degradation takes place more rapidly than mineral oil (for only a few weeks), called rapidly biodegradable. Biodegradation is possible whenever you meet the following prerequisites:

- presence of micro-organisms;
- presence of oxygen breathing organisms;
- presence of nitrogen and phosphorus compounds for feeding microorganisms;
- the appropriate temperature, because the biological degradation carried out in a warmer environment is faster than in the mild or cold environment;
- lubricant must not be contaminated by substances that kill microorganisms or render them ineffective.

What is still a problem is the methodology that was used to determine biodegradable potential. The experience in the use of bio-oils is still insufficient to have total clear picture of ecological footprint of bio-oils. We still do not have full information on the operation of bio-oils in complex organisms, in the sense that the degradation path in the environment has not yet been identified , especially the issue of inclusion in food chains and consequently to bioaccumulation.

Table 2: Biodegradability of Lubricating Oil
Source: Mudge, 2010

Base fluids	Biodegradibility, %	
	„EPA" method*	„CEC" method*
Mineral base oil	42 – 48	20-40
Vegetable oil	72 – 80	90 – 98
Polyglycol	6 – 38	-
Sinthetic esters	55-84	90-100

*EPA Environmental Protection Agency, USA; CEC - Coordinating European Council

According to the norms of the EEL - European Ecolabel for Lubricants, sawchain oils belong to the group III (complete loss of lubricant during use). Rapeseed oil is the most environmentally and commonly used base fluid for production of bio-saw chain oils. The experience of many chainsaws producers, as well as users, are mostly in favor of biooils based on rapeseed oil in terms of better lubrication and adhesion compared to conventional oils.

Table 3. shows the results of testing the biodegradability of oil, ecotoxicity and impact on water.

Table 3: Testing the biodegradability of oil, ecotoxicity and impact on water

Characteristics	Unit	Method	RE*	BT*	MT*	Request
Biodegradability	%	OECD 301B-Sturm,28	76	65	30	>60
	%	CEC L-33-A-93, 21 dan	97	90	35	>80
Ecotoxicity	mg/L	OECD 202 (EC 50)	>1000	400	10	>100
Impact on water		WGK	0	1	3	≤1

**RE - rapeseed*
**BT - biodegradabile sawchain oil*
**MT - conventional sawchain oil (referent oil)*

Results of testing the biodegradability of pure vegetable oils RE (no additives) indicated a rapid biodegradability and non-toxicity of vegetable oils without compromising the aquatic environment. Biotesterol BT shows rapid biodegradability. Sample MT does not satisfy the requirements of biodegradability.

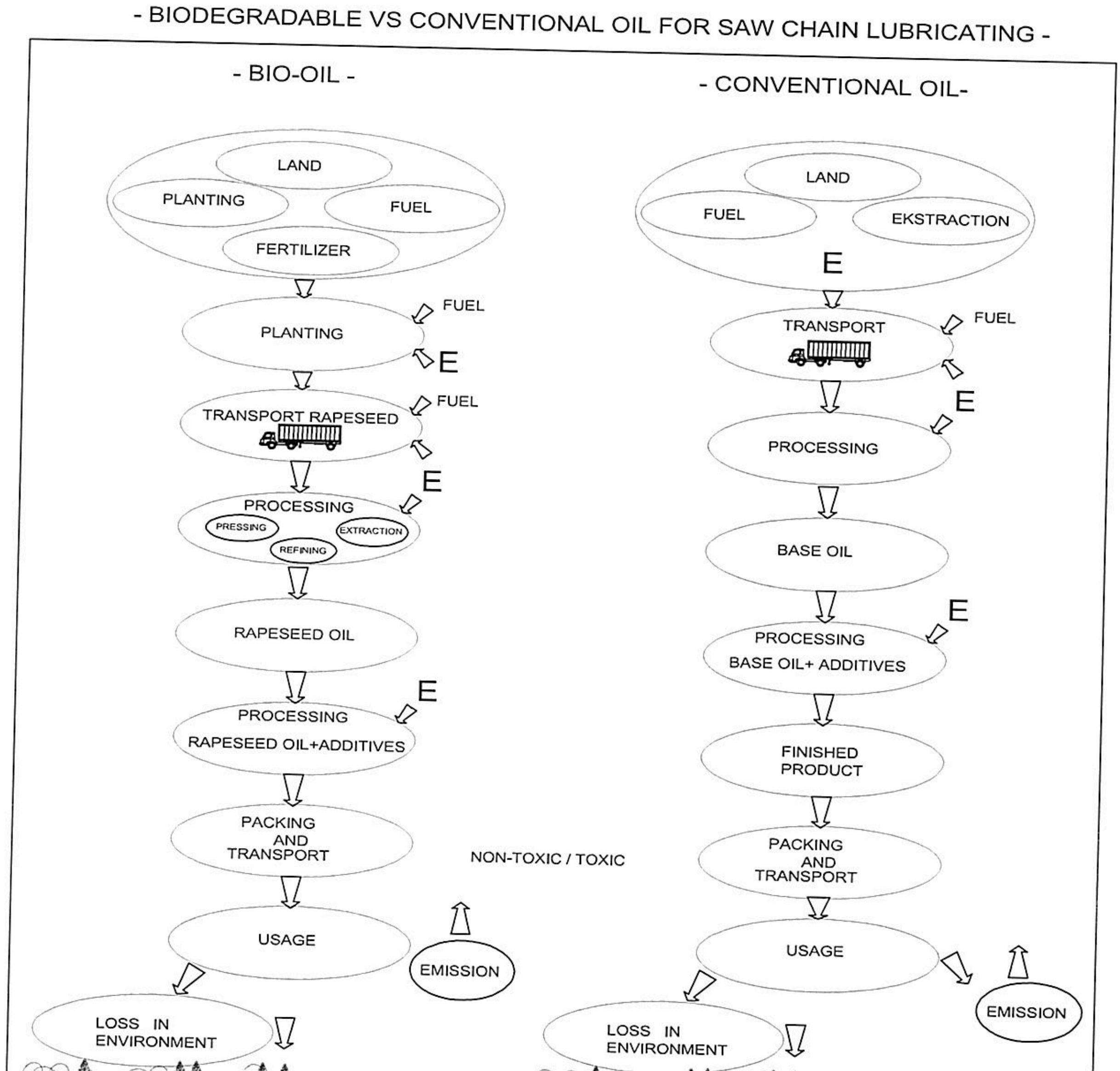

Figure 8: Production chain of bio- and conventional lubricants - LCS (Life Cycle Stages) of a biolubricant and a mineral lubricant (source: Reinhardt et al, 2002)

The current situation of bio- compared to conventional lubricants on the market is typically portrayed as in the diagram below. However, if we succeed to demonstrate more clearly environmental benefits at a reasonable difference in price, the market would faster and easier accept certain financial costs for the sake of a lower degree of negative impact on the environment.

Figure 9 shows the overall difference between the total costs of using conventional lubricants in relation to bio lubricants.

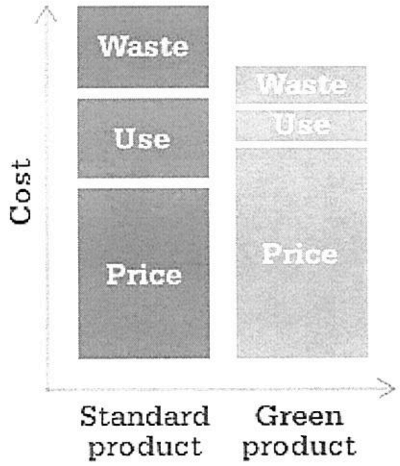

Figure 9:Total costs of using conventional lubricants in relation to biolubricants

Future research regarding the development of production process of bio-lubricants must aime at lowering production costs, technical requirements and biodegradability. Also, development of environmentally suitable base fluids must be accompanied with development of new generation of additives that are safe for the environment. To ensure that the development of the lubricant is on the right path, it is needed to develope the new methodologically concept of biodegradability.

First of all, everything that is biodegradable does not necessarily mean that it is safe for the environment, because of the intermediate products in the decomposition cycle. At the end, solving the problem of waste oil can significantly cause the fluctuations on the market, primarily by using cheaper, biological processes and technologies.

Conclusion

Results comparing the impact of the life cycle of bio- and conventional oil are recognized initially at the level of the indicator of certain categories of influence, and then at the level of the weighted indicator of the overall impact on the environment, including the economic section of production costs and possible environmental damage. Comparison of biodegradable lubricants with conventional lubricant exhibits some environmental benefits, although it is difficult to assess accurative and objectively. If we could environmental considerations expressed in purely economic terms and thus make the comparison more precisely. The sooner as we elaborate elements which can accurately determine the environmental damage and translate them into the language of economics, this image will be clearer and more complete.

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