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Evaluating of potential impacts of liquid detergent using life cycle assessment methodology

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ABSTRACT/RESUME

Abstract : *The goal of this study was to use life cycle assessment (LCA) methodology to assess the environmental impact of liquid detergent intended for dish, clothes and multi user, which is produced by a leader manufactory in Algeria town. This LCA was used to evaluate the environmental impact generated by this company and to determine the contribution of compound to impacts evaluated, and to try to carry out a comparative study between these products.*
This study seems to be in need of using of SimaPro7.1 software and EDIP 2003 method.
The input data needed to conduct Life Cycle Inventory (LCI) coming from this factory, which use different raw material imported from European and Asian countries, energy used is coming from Algerian resource. Outputs are the result of wastewater analysis of this factory in different forms (liquid, solid and gas form).

I. Introduction

Surfactants or surface-active agents represent potential toxicants. They have many applications in both domestic and industrial operations. Combined worldwide consumption of surfactants (anionic, cationic and nonionic) was estimated to be 15 million metric tons in 1989. [1]
Detergents and cleaning agents have received specific attention, mainly because the high consumption, for example, in 1993, EC used to consume an average of 5.5 Million tons of detergent. Therefore, focus on this category of products seems to become necessary as far as ecology is concerned.

In 1992, the association of the Swiss Soap and detergent industry (SWI), commissioned LCAs on detergents and cleaning agents, considered the eco-balancing, the essential ingredients of these product categories are an important step for the sake of developing European detergent market [2].

The popularity of synthetic detergents raised a particular interest for the effect of surfactants on the growth and metabolism of plants, on ground water and wastewater operations.

Removal of the residual surfactants for the effluents steams is a very important task, however imposing expensive physical and chemical processes. [3]

Synthetic surfactants are widely used, they appear in natural ecosystems either through direct application. Possible harmful effects of surfactants in the environment are the re-mobilization of organic pollutants, the inhibition of biological activities, and toxic effect against organisms [4].

In the Algerian society, a great consumption of detergent product is so remarkable in the last 10 years that many factories are installed with different types and markets. For this reason, the evaluation of impacts generated by these manufactories seems to be necessary. The work reported in the current study is the use of life cycle assessment methodology in order to assess the environmental impacts generated by one of the leader manufactories on detergent production in Algeria town. The LCA is also used to show how elements generate the impacts categories and to compare three liquid detergent for different use: washing dish, clothes and multi user detergents.

The LCA is a methodology developed to evaluate the mass balance of inputs and outputs of systems, and to organize and convert those inputs and outputs into environmental categories impacts, relative to resources use, human health and ecological area [4]. This methodology has taken place within ISO 14040 series [5] [6] [7] [8].

The impacts are evaluated using SimaPro.7.1 Software and EDIP 2003 method.

II.Description of system

For preparing these kinds of liquid detergent, we must have a mixture of the compound with addition of water to obtain a homogeny liquid with middle viscosity and neutral Ph.

Principal compounds are anionic surfactants that are LAS (linear alkyl benzene sulfonate) and AES (alkyl ether sulfonate), which are neutralized with sodium hydroxide, and nonionic surfactant (fatty alcohol) NI07 that has an emulsifying role, with helices agitation and rapid speed.

III.Material and methods

In order to determine the environmental impact of liquid detergent production, and for the sake of carrying out a comparative study, we need to use the LCA methodology using SimaPro 7.1 and EDIP 2003 method.

a. Life cycle assessment

Life cycle assessment (LCA) is a method of evaluation used to assess the environmental impacts of technologies from "cradle to grave" and may be performed on both products and processes. LCA has the ability to evaluate the materials and energy efficiency of a system and to identify pollution generated by production system and favor.

LCA has been proved to be a potential tool for evaluating the improvement of industrial processes, used to avoid sub-optimization in the development of more environmental and concrete product and manufacturing processes.

LCA is developed to evaluate the masse balance of inputs and outputs of system and to convert those inputs and outputs into environmental themes or categories relative to resources use, human health and ecological areas [4] [9].

b. Goal and scope, functional unit and system boundaries

The goal of the present study is to assess the environmental performance of detergent production by comparing them. The model focuses on production of detergent liquid form that are: multi user liquid, liquid dish and liquid for washing clothe, the production process includes the mixture of all compounds in aqueous solution. The functional unit of analysis in this study is the production of one ton of this detergent.

c. Data quality

The study is based on the process data supplied by detergent production in Algerian manufactory. Data used for this study is based on data records from the plants.

The LCIs of the ingredients manufacturing processes for multi user liquid detergent and dish liquid detergent is obtained from this plant and are reported to production of one ton of final product.

The LCI of the packaging needed to construct package is calculated from the raw materials (cardboard, plastics PEHD …).

The consumption of energy and water is reported to quantity of final product.

Emission and characteristics of wastewater and waste generated are considered.

The LCA SimaPro7.1 (Preconsultants, 2008) is used to evaluate the environmental impact of inventory aspects. Inventory data for raw materials and electricity and water is obtained fromthis factory and from SimaPro.7 software databases (table 1 show raw materials and energy resources used in this factory).

Table 1. *Life cycle inventory of liquid detergent*

Raw materials consumption (kg)	**Multi user**	**Dish liquid**	**Liquid clothe**
LAS (linear alkyl benzensulfonat)	21.207	27.455	44.5
AES (alkyl ethersulfonat)	26.414	32.189	0
Sodium hydroxid (NaOH)	0.526	0.681	26.14
Sodium Chlorure (NaCl)	4.260	3.806	16.34
Fragrance	1.230	1.136	6.63
Formaldehyd	0.662	0.662	2.86
Fatty alcoholethoxylate (NI 7)	3.787	0	14.88
Dequest (sequestrant agent)	0.568	0	0
Stearicacid	0	0	7.96
Hydro nacre	0	0	6.63
Tartrazine yellow color	0.153	0.153	0 .5
Acétiqueacid	0.037	0.037	0
Packaging consumption			
Cartonscellulose (cardboard) (Kg)	50	33.33	104.49
Etiquettes (plastics) (Kg)	3.60	2.40	4.64
Bouchons (PEHD) (Kg)	4.80	3.20	2.6
Bottle (PET) (Kg)	48	32	46
Energy consumption			
Electricity (KWh)	32.14	21.43	15.24
Water (m^3)	941.18	932.89	737.6
Emission parameter of effluent			
Température (°C)	20	20	21
Ph	9.07	10.30	6.98
DCO (mg of O_2 / l)	983.00	1440.00	1540
DBO_5 (mg of O_2/ l)	103.33	400.00	130
LAS (g/l)	1.96	2.018	0.56
AES (g/l)	0.650	0.710	0
NI 7 (g/l)	0.068	0	0
Turbidity (NTU)	71.11	5.93	4.76
L'O_2 dessous (mg/l)	13.32	10.92	8.76
Phosphate (mg/l)	76.00	33.00	0
Sulfate (mg/l)	800.00	1400.0	530
Nitrate (mg/l)	30.00	30.00	20.56
TDS (complete dissolved selt (g/l)	3.45	4.09	2.55
Waste generated			
Cartoncellulose (kg)	5	10	4.05
Plastics (kg)	2	1.5	3.37

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d. *Impacts assessment*

The EDIP2003 method is used to assess the environmental impacts.

The impacts considered in this study are shown in figure 1, and summarized in table 2:

- Aquatic eutrophication EP(N) expressed on kg N
- Aquatic eutrophication EP(P) expressed on kg p
- Human toxicity water expressed on m ^{3}
- Bulk waste expressed on Kg.

Table 2. *Impact generated by detergent liquid detergent -EDIP 2003 method-*

Impact categories	Unit	Multi user	Dish liquid	Liquid clothe
Aquatic eutrophication EP(N)	*Kg*	4.07 E-6	4.07 E-6	1.26E-7
Aquatic eutrophication EP(P)	Kg	2.21 E^{-5}	9.58 E^{-6}	0
Human tocxicitywater	m^3	0.105	0.00738	0
Bulkwaste	Kg	7.00	11.5	3.67

Table 3. *Contribution to impact generated*

Impact Categorie	Element co-nntribution	unit	Multi user	Dish liquid	Liquid clothe
Aquatic eutrophication EP(N)	*Nitrate*	*Kg N*	4.07 E-6	4.07 E -6	1.26 E-7
Aquaticeutrophication EP(P)	*Phosphate*	Kg P	2.21 E-5	9.58 E -6	0
Human tocxicity water	*Fatty alcohol ether sulphate (C12 - C14)*	m^3	0.00178	0.0021	0
	Fattyalcoholethoxylate	m^3	0.103	0	0
	Linear alkyl benzensulfonate	m^3	0	0.0053	0
Bulkwaste	*Carton waste*	Kg	5.00	10	0.3
	Plastic waste	Kg	2.00	1.5	3.37

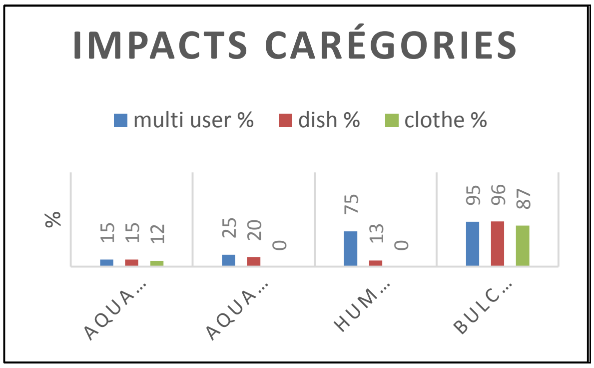

Figure 1*. Impacts category of liquid detergent*

IV. Results and discussion

In this case, the production of multi-use liquid detergent and dish liquid detergent generates four major impact categories, which are:

a) Aquatic eutrophication

This impact has been evaluated at 4.07 E-6 kg N, and at 2.21 E-5 kg P respectively due to nitrate and phosphate contribution in the case of multi-use liquid detergent. It has been evaluated at 4.07 E-6 kg N and at 9.58 E-6 kg P respectively due to nitrate and phosphate contribution in the case of dish liquid detergent.

The phosphate contribution is very important in the case of multi-use than dish liquid and it has no contribution in case of detergent liquid clothe, because we have used more surfactant (tow anionic and one nonionic) and dequest (sequestrate agent) in the case of multi-use. In the case of dish liquid and liquid clothe, we have used only the anionic surfactant, without using dequest. We can say that dequest partly contributes to eutrophication impact because it contains phosphate and nitrate in it composition. The use of surfactant undergoes a degradation of organic content, which contributes to eutrophication impact, that is also due to change of the formulation (important difference, see table 1).

The same result is obtained by Erwan Saouter and all [10], it is shown that application of LCA methodology using CML92 method for granular laundry detergent, this production generates the eutrophication impact due to biodegradation of organic materials by oxygen depletion and nutrients, phosphorus and nitrogen. The residual detergent ingredient is converted to chemical oxygen demand (COD). This study has made use of the results obtained in 1998, the eutrophication impact generated by phosphorus in the Netherlands and Sweden respectively with1380 and 1360 expressed on mg PO_4^{-3} for granular laundry detergent.

A study carried out byJoostDewaele and al [12] demonstrates that formulation step of ARIEL liquid detergent for washing clothe in France, contributes to eutrophication impact at 9.82% and 8.32% respectively in 1998 and 2001, this step consumes also an average of 0.7 to 0.95% of water for the same years. The same study demonstrates for the most detergent product (liquid form and different use) formulation contributes at 7% to 15% to this impact generated.

Eutrophication is primarily driven by organic emissions, since all formulations under study are free of phosphate. Noteworthy is that today's powders and liquids are >40% lower on eutrophication [15].

b) Human toxicity water

In this case, it has generated at $0.105m^3$ for multi-use and 0.00738 for dish liquid, which is applied to residual detergent ingredients in the effluent. In this case it is due to alkyl ether sulfonate (AES) with contribution at $0.00178\ m^3$ (so 1.7%) of total impact and to fatty alcohol ethoxylate (NI 7) with 0.103 m3 (so 98.3%) of total multi-use impact. It is due to the linear alkyl benzene sulfonate (LAS) and AES in the case of dish liquid. Those kinds of component are the residual product (mark) of anionic and nonionic surfactant generally present in the effluent.

These compounds are present at significant concentration in the effluent of this plant (see table1), so they WERE being discharged into the environment without treatment.

Several studies of rivers and estuaries have reported concentration of anionic surfactant such as LAS, AES at the µg/L level. In the case of nonionic surfactant such as AEO, it has been detected in sewage plant influent and effluent samples ranging at levels between 1 and 30 µg/L [11].

A study carried out by Joost Dewaele and al [12] demonstrates that formulation and use stage are the principal and dominant contributor to this impact at 28.28%, 23.88% respectively for 1998 and 2001for all kinds of detergent formulation, in which $NO_x$and SO_x emission are accounting for > 90% of human toxicity potential.

Pant and al [13, 14] have identified that the most impact toxic is linked to the wastewater from washing process and formulation.

By this study we can say that using only anionic surfactant without using nonionic is very benefit, so they generate low quantity of impact because nonionic contribute considerably to impact human toxicity water.

Therefore, it is very important to replace nonionic by another emulsifying compound that has low impact to environment.

c) Bulk waste

In this case, it has generated 7kg of waste by production of one ton of final product; this is due to carton and plastic waste packaging contribution.

JoostDewaele and al [12], demonstrate that a significant part of total solid waste of various product (liquid and powder), is derived from the packaging disposal (with a relative higher share for the liquid detergent). Solid waste produced during the product formulation, and the accounted solid waste is derived from wastewater treatment (36 - 48%), within the waste water treatment, 98% of the solid waste is produced as chemical absorbed into sludge. It is also due to not evaluating refile packaging.

V.Conclusion

Life cycle assessment is used to evaluate the environmental impacts generated by detergent production. The current study demonstrates a presence of eutrophication impact due to nitrate and phosphate that are the residue of surfactant after their biodegradation. It is present in the effluent rejected without treatment by this factory in the environment area, human toxicity water is due to surfactant. Therefore, it is important to reformulate the detergent composition using natural surfactant, or minimize the quantity used and treating the effluent.

The LCA is a beneficial tool in evaluating the environmental impact in that it shows how element contribute to the appearance of all impacts' categories; it is also helpful in the process of decision making for the sake of minimizing the potential impacts.

The findings of the current humble study seem to be consistent with its expressed objectives. Accordingly, the results appear reliable under study limitations.

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