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FROM ENVIRONMENTAL ASSESSMENT TO USAGE CENTERED ECO-DESIGN: TAKING INTO ACCOUNT THE REAL IMPACT OF CONTAINER-CONTENT SYSTEM FOR THE LIQUID LAUNDRY DETERGENT

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ABSTRACT
It is shown in a study focusing on the use laundry detergents that are eco-designed provide no environmental gain (Chapotot et al., 2011). However, in this work aforementioned, there is no influence consideration on the environmental assessment of laundry detergent packaging themselves, nor the effects of logistical impact is expected to be also reduced by eco-designed solutions (insurance gain weight to transport). Here we study how this behavior influences the environmental impact of the packaging itself and of the complete product (washing, packaging and logistic). Taking into account the container-content system of laundry detergent, we show that neglecting the real behavior of users induces the risk of underachievement design. The eco-design of packaging cannot be reduced to a material choice or mass limitation of this package. It is in the way it performs on the effective consumption of the material contained that it has its greatest usefulness and influence.

Keywords: human behaviour in design, eco design, user centred design, friendly design, packaging

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1 IMPACT AND USE OF THE LAUNDRY DETERGENT

In recent years, industries began to “ride the wave” of eco-design, intending to create cleaner products with a reduced impact on the environment. The interest of this approach is to focus on fast-moving consumer goods. Such products are widely used by people, and should be the first candidates to benefit from an ecological re-design.

Laundry detergent is such a product, with a high potential for this "transformation”. We can note that the laundry industry has been working for over 10 years to reduce pollution from their detergents (Saouter et al., 2002). One of the last of the series is super concentrated liquid laundry detergent. It has been shown that focusing on the use laundry detergents that are eco-designed provides no environmental gain (Chapotot *et al*., 2011). The authors analyze the behavior and real use of laundry detergent consumers in comparison to the recommended doses available on the back of the detergent bottle. This previous study reveals that theoretical and real uses of laundry detergent are very different at the advantage of the regular detergent. Thus, the user behavior allowed highlighting eco-design “badly mastered” and the importance to engender a usage centered eco-design approach.

However, in the aforementioned work, there is no influence consideration on the environmental assessment of laundry detergent packaging itself, nor the effects of logistical impact is expected to be also reduced by eco-designed solutions (insurance gain weight to transport). Also, according to the study by the Packaging National Council (CNE, 2007), it is shown super-concentrate compared to regular laundry detergent packaging provides: 57.8% gain in terms of weight in primary packaging compared to 53.1% of the overall packaging considering the theoretical use.

The previous study showed the role of actual consumer behavior on the destruction of environmental benefits expected by a new formulation of detergent. *Here we study how this behavior influences the environmental impact of the packaging itself and of the complete product (washing, packaging and logistic).* Currently many performance m easures of eco design package are associated with the measurement of mass and volume of packaging contents / volume container. This very fragmentary approach applied to consumer products seems dangerous because we do not allow measuring the actual environmental efficiency of the final proposed product. The consumer behavior take into account concerns the step of washing and of sort of the packaging waste. To conduct this analysis we consider 2 sorts of products: a regular and a super concentrate laundry detergents. Taking into account the container-content system of laundry detergent, we show that neglecting the real behavior of users induces the risk of underachievement design. The eco-design of packaging cannot be reduced to a material choice or mass limitation of this package. It is in the way it performs on the effective consumption of the material contained that it has its greatest usefulness and influence.

Thus, in this paper, we present first the figures and standards linked to the packaging end-of-life. With use-centered approach, we also introduce consumer behavior toward waste sorting. After the presentation of our research hypotheses, we describe the development of our experimental protocol and the construction of the ecological profile. Finally, we conclude this paper with the results of our study and discussion.

2 END-OF-LIFE OF THE PACKAGING AND SELECTIVE SORTING

2.1 Few figures

The volume of waste generated in the EU is estimated at 1.3 billion tons per year, including 241 millions tons of household waste (OJEU, 2006). This value has a high variability as the quantity of packaging waste heavily depends on the place of residence: in rural zone it averages at 30 kg/capita/year and reaches 56 kg/capita/year in urban zones (Eurostats, 2012). European Directives 94/62/CE and 2004/12/CE fix the performances to be achieved by member states in terms of eco-design and management of packaging end-of-life. The instructions recommend promoting (in order of importance):

- source reduction (reducing the amount of material used while respecting good physical and sanitary product packaging protection practices)
- re-use of packaging (without transformation of the shape and the material)
- recycling of used materials and use of recycled materials.

These texts also set performance levels to be achieved by the end-of-life sectors of EU states for the year 2008. Those performance targets (percentage are given in weight of the material):

- Minimum 60% of packaging waste should be recycled or incinerated at waste incineration plants with energy recovery;
- 55% to 80% of packaging waste should be recycled;
- Recycling targets: no later than 31 December 2008 the following minimum recycling targets for materials contained in packaging waste should have been attained:
    - 60% for glass;
    - 60% for paper and cardboard;
    - 50% for metals;
    - 22.5% for plastics, counting exclusively material that is recycled back into plastics;
    - 15% for wood.

The figures provided by France in December 2008 show that it only reaches 56.4% of the total volume of recycling of its packaging, its performance in the recycling of various materials were close to the permissible limits and really insufficient in the case of wood (Eurostats, 2012).

2.2 Consumer behaviour

In France, 35% of waste sorting are incorrectly placed in the sorting bins and incinerated without energy recovery (Ademe, 2009). We expect that it could be avoided by informing consumers about best practices (the right packaging in the correct bin), as highlighted by Table 1.

Table 1: Percentage on the plastic packaging sorting (ADEME, 2009)

	Thrown out in the bin with household garbage	Thrown out in the bin for waste sorting	Respects the sorting instruction AND is QUITE SURE of his/her act	ERROR AND is QUITE SURE of his/her act (misconception)
Water bottle	4%	95%	79%	3%
Milk bottle	5%	92%	70%	2%
Laundry detergent bottle	13%	84%	57%	6%
Household product bottle	16%	82%	52%	6%
Shampoo bottle	30%	68%	42%	11%
Oil bottle	31%	68%	41%	17%

As a first step, the study which we conducted focuses on the bottles of laundry detergent and according to the "Eco-Emballage" study by the end of 2009; we can see that 57% of people who sort their laundry bottles are sure of what they do. However, 6% of consumers mistakenly sort their bottles while being confident in their act. These figures show that on one hand there is still a large part of the population who does not sort its plastic packaging; and on the other hand that a small part of those who sort do not necessarily sort correctly. Currently in France, more than 5 bottles or plastic container on 10 are sorted by the inhabitants. In 10 years, the recycling of plastics has been multiplied by 5 (Valorplast, 2010).The reasons of this evolution can be associated with the growing part of the French eco-friendly population and by ADEME's advertising promotion on the necessity to reduce the waste stream for a better respect of the environment. Know-how, associated with sorting is not the only reason that can explain low levels of sorting. Influential factors have already been shown, such as the lack of space for sorting bins in the consumers' homes or the lack of motivation from residents to go down to the building's or neighborhood's common sorting bins (Vargas Julian 2010).

In addition, Bertololini (1996) identified factors (size of the kitchen, existence of storage space) influencing the consumers' willingness to sort (see Table 2). He highlighted a link between the sorting rate and ease of storing sorted waste.

Reduction of the packaging waste stream is an important objective of European Union, and the volume of wastes concerned could explain that. However, it is important to consider the importance of this issue in relation to the composition of detergent, logistics and use of detergent at home.

Table 2: Behavior faced with waste sorting (Bertololini, 1996)

	Size of the kitchen		
	Big	**Middle**	**Small**
Share of people who sort regularly	35%	25%	8%
Share of people who do not sort or irregularly	28%	32%	46%
	Existence of storage space		
	Junk room	**Cupboard**	**Balcony**	**No area**
Share of people who sort regularly	34%	27%	19%	13%
Share of people who do not sort or irregularly	28%	30%	35%	42%

3 SCOPE OF WORK

3.1 Questions

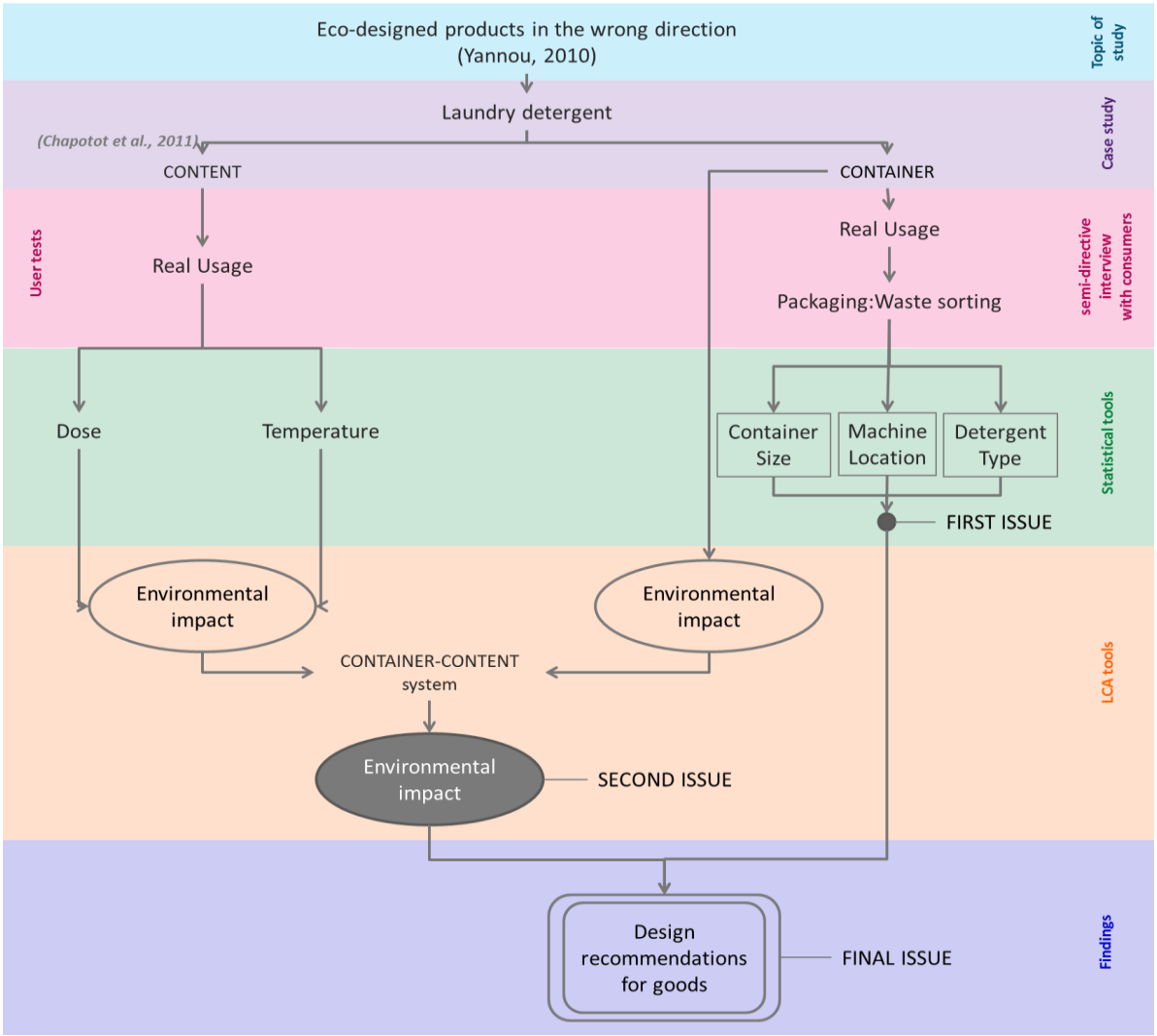

Figure 1: Scope of work

Our research focuses on two aspects that influence the final environmental impact of the detergent in function of the user's real behavior.

The first issue concerns the user's behavior and his / her consent to sort the container: what are the factors that influence the French consumers consent to sort the laundry container? Our interest is focused on three factors liable to influence the consumer behavior: the location of the washing machine at users' home, the size of the container and the type of laundry detergent used (regular and super-concentrate)

The second issue concerns the impact of the actual behavior of users in their dosage of detergent. We measure this impact not only in terms of used volume of detergent but by also taking into account the packaging and transport (as smaller bottles should mean a lesser environmental impact from those factors).
Thus, our second question refers to the real environmental impact of the super-concentrate laundry detergent (called eco-designed detergent). We are interested in the environmental impact, taking into account the real behavior of consumers (noted during tests and interviews) and taking into account the container-content system in comparison to the study already conducted in 2011 which took into account only the contents of the laundry detergent (Chapotot *et al*., 2011).

3.2 Method

Consumers Approach

Identifying and defining the influencing factors and the real environmental impact of the product requires knowing the users' behavior when faced with waste sorting. To achieve so, we have conducted a campaign of semi-structured interviews with a questionnaire for support. This questionnaire has been developed to allow us answering one main question: What are the factors that influence the willingness to sort waste? (Influence of the type of laundry detergent, the bottle size and location of the washing machine in the home)

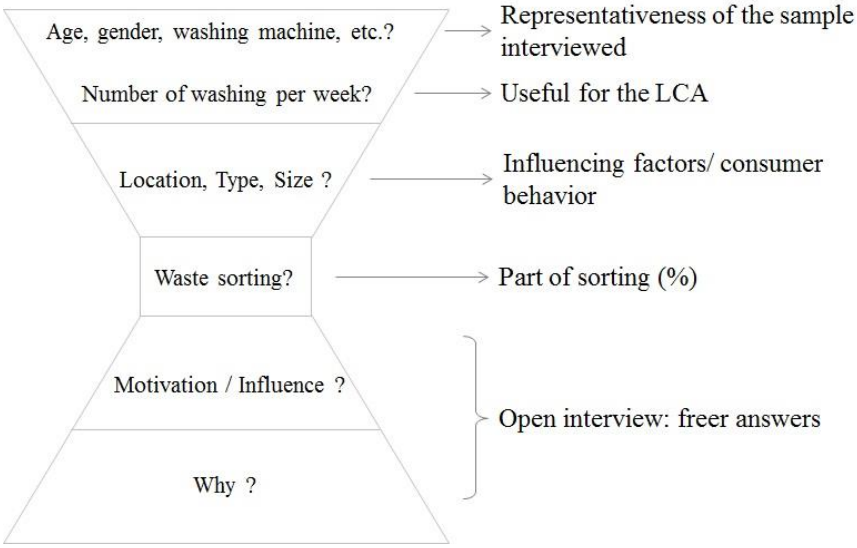

Figure 2: Questionnaire structure

We used a "hourglass" structure to conduct the interviews (see figure 2).We started with very open questions at first, semi-open question afterwards for narrowing the answers, and reopen the issues in the end. Reopening the questionnaire is mainly useful to increase the feeling of freedom of the interviewed persons. Moreover these last questions allow identifying some factors we would not have considered beforehand (e.g. mailmen).
In this context, the scope of our campaign is essentially dictated by our sample of users. The targeted consumer profile is a person, man or woman, living in the Paris region, owning a washing machine or not and commonly using a regular or super-concentrate liquid detergent. In terms of usage, these two products are distinguished by their dosage and recommended washing temperature. In the case of regular detergent, it is advisable to wash between 30 and 40°C and to dose with 120ml (average). The super-concentrated product should be used at a temperature between 15-20°C and a dose of 37 ml (roughly one third of the volume of regulare detergent)..

Data, Functional Unit and perimeter considered in the detergents' packaging LCAs

The LCAs were performed using Simapro V7 and the Ecoinvent V2.0 database. Every LCIA simulations were conducted with the ReCiPe V1.03 characterization method, Hierarchist (H) version and European weighting for single score calculation. 18 characterization impact categories are

available. However we reduced the number of categories to the six following: Climate change, Ozone Depletion, Human Toxicity, Fresh Water Eutrophication, Terrestrial Eco toxicity.
This choice is coherent with the recommendations of the working group constituted in France to define an environmental label for the goods of consumption (BP X30-323-0, 2011).
We realized four comparative LCAs which a functional unit was to ensure a year of laundry so 202,28 washings per year.
For the two first LCA we modeled the theoretical consumption of detergent for a regular and super concentered liquid detergent. In two following LCA we modeled the real rate of consumption of these sort of detergent identified in the previous study (Chapotot *et al.*, 2011). Scenario considered for the end of life of the packaging are those of the French recovery system (percentages of sorting, recycling and landfill associated with the French plastics house wastes).
In these four cases we consider a similar perimeter which is defined in the table 3.

Table 3: Perimeter of the four LCA conducted in our study.

	Included	**Excluded**
Production	Manufacture of the cap and of the container Quantity and nature of materials used in the package. Formulation of the detergent (natures and quantities of ingredients).	Secondary and tertiary packages and their production. Process of manufacture for the detergents.
Transportation	330 kms traveled by 16 t truck between plant packaged detergents and point of sale.	Traveled upstream of the plant and between the supermarket and the consumers' houses.
Use	3,89 washing/weeks = 202,28 washing /year Theoretical amount of regular washing detergent for one dose : 120 ml Real amount : 76 ml Theoretical amount of super concentrated washing detergent for one dose : 30 ml Real amount : 58,75 ml	The volume of water, energy and waste generated by the washing phase.
End of Life	French scenario with the specific parts of materials recycled, incinerated, landfilled.	The transportation to incineration plant, landfill, recycling plant

The composition of the two packages analyzed is given in the table 4:

Table 4: Data employed for the models of the packages

	Super Concentered Liquid detergent	**Regular Liquid detergent**
Cap	15g of Polypropylene Injection process	6g of Polypropylene Injection process
Container	45g of Polypropylene Injection process	107g of High Density Polypropylene ethylene Injection process
Dosing	10g of Polypropylene Blowing process	8g of High Density Polypropylene ethylene Injection process

Energetic mix uses is the French value includes in Ecoinvent database.

4 STATISTICAL ANALYSIS AND RESULTS

Data analysis from the campaign interviews has been conducted on a sample of N= 78 consumers. This sample is mainly represented by an equal amount of men and women and includes:

- 1.3% of people aged under 20
- 57.7% of people aged between 20 and 35
- 21.8% of people between 36 and 49

- And 19.2% of people over 50 years.

4.1 Influence of the washing machine location

In our study we wanted to verify if the location of the washer in the home could influence the users behavior faced with the sorting their detergent empty bottles.
We identify five "categories" location, i.e. no washing machine, Bathroom, Linen room, Kitchen and Other.
We use the chi-square test (Pearson) as our research comprises two groups (location of the washing machine tested 2-2) and a qualitativedependent variable is qualitative (the answer to the question "do you practice waste sorting with your laundry bottle? ").

Table 5: Result of the chi-square tests

	no washer	Bathroom	Linen room	Kitchen	Other
no washer					
Bathroom	Null				
Linen room	Null	Null			
Kitchen	Null	Significant	Null		
Other	Null	Null	Null	Significant	

The data analysis of this research indicates that consent to sort is more important when the machine is in the kitchen.

4.2 Influence of the bottle size

We use the significance test (or R) as our research has two quantitative variables (bottle size and percentage of performed sorting). We use this test because we want to establish a relation between the bottle size and the percentage of performed sorting. More specifically, we want to verify the influence of the bottle size on the user behavior faced with sorting.
In our case study we identify four most commonly used bottle sizes (according to 2 types of detergent considered: super-concentrate and regular): 1L, 1.5L, 2L and 3L.
We considered the following statistical hypotheses:
H0: The relation between the bottle size and the percentage of sorting performed is due to coincidence
H1: There is a relation between the bottle size and the percentage of sorting performed.

Table 6: Result of the significance test

Variables	**N**	**R**	**P-value**
Bottle size	74	0.978	0.0219
% of sorting performed			

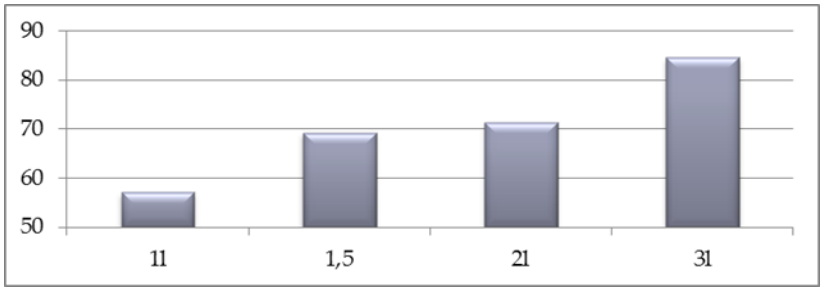

Figure 3: Result of the influence of the bottle size on the percentage of sorting performed

The data analysis of this research shows that there is a relation between the bottles size and the percentage of sorting done and this relation is high (R = 0,978, p = 0,002). T larger the bottle, the higher the percentage of sorting performed (see Figure 3).

4.3 Influence of laundry detergent type

We use the chi-square test (Pearson) because our research comprises two groups (the users of super-concentrate and those who use regular laundry detergent) and a qualitative dependent (here the answer to the question "do you practice waste sorting with your laundry bottle? "). Finally, we use this test because we want to compare the frequencies of these two groups to infer a relation between X (detergent type) and Y (the answers - yes or no).

We considered the following statistical hypotheses:H0: There is no difference between people who use regular detergents and super-concentrate according to their behavior faced with packaging sorting.

H1: There is a difference in sorting habits for the two groups of users.

Table 7: Result of the chi-square test

Indicator	Groups	N	F- Yes	χ^2	P-value
Packaging sorting	Regular	66	48	0,65	0,41
	Super-concentrate	12	8		

The data analysis of this research indicates that users of regular laundry detergent practice more waste sorting (48/66= 72.3%) than users of super-concentrate (8/12= 66.6%). The difference between the two groups is not significant (chi-square = 0,65, df = 1, p = 0,41). We can therefore conclude that the type of laundry detergent used does not influence the behavior of users faced with waste sorting.

4.4 Environmental Impacts generated by the theoretical and real consumptions including detergent, packaging and distribution

We compare (Figure 4) impacts of the detergents without take into account the packages, in first with a consumption in accord with the producer recommendations (4a) and second with the real levels (4b) of consumption (Chapotot *et al.*, 2011) for the regular and super concentrate laundry detergents.

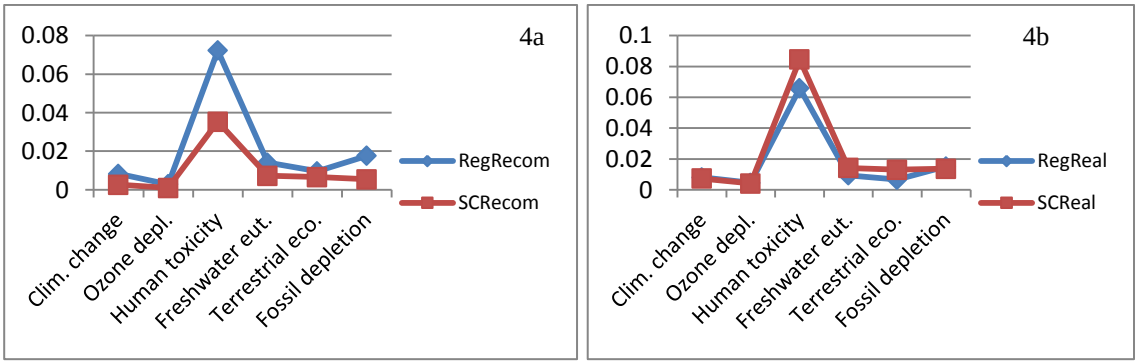

Figure 4: Environmental impacts (for one year of a French family) of Regular (Reg) and Super Concentrate laundry detergents with theoretical (4a) and real (4b) consumptions.

The actual behavior of the consumers implies an overdose of super concentrated and an under dosing of the regular laundry detergent (Chapotot *et al.*, 2011). Consequently, the result is contrary to that expected: super concentrated laundry is dirtier to use. A similar consequence is observed in the case of the packaging's themselves (Figure 5).

In this specific case there are few variation of environmental impact in the theoretical case but with the real values the situation of the regular detergent are much less detrimental than the super concentrated detergent.

Taking into account the transport of 300 km by truck in addition to the detergents and their packagings (Figure 6), magnitude's order of the environmental impacts for the real situations are very strongly amplified. The final effect of super concentrated detergent and its packaging use increases the weight of material transported and consequently its environmental impacts. Traditional laundry detergent is to actually less impacting.

The authors point out that all the results showed in this chapter were calculated using national waste sorting and not the results of the previous survey the behavior of the consumers.

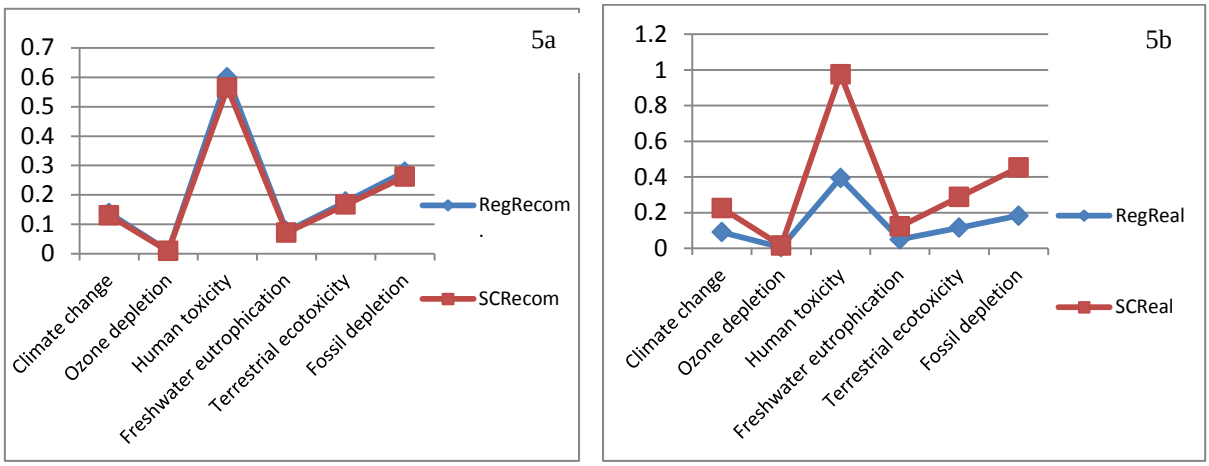

Figure 5: Environmental impacts (for one year of a French family) of Regular (Reg) Packaging and Super Concentrate laundry detergents packaging with theoretical (5a) and real (5b) consumptions.

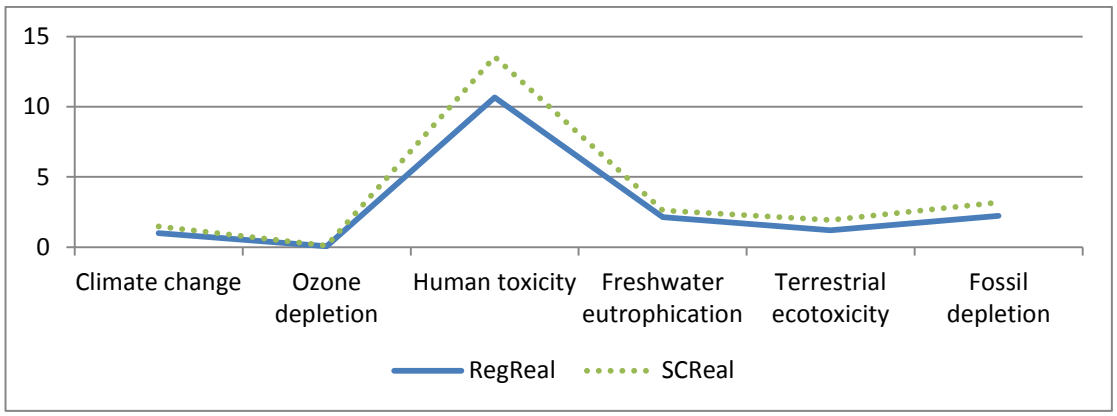

Figure 6: Comparative Environmental impacts of one year of real consumption of regular and super concentrated laundry detergent, taking into account (Detergent+ packaging +travel in truck – 300kms).

5 DISCUSSION & CONCLUSION

The scenario modeled for the LCAs to compare the environmental impacts of regular and super concentrated detergents highlights two situations antagonists. First, with the theoretical dosages, the super concentrated has a better environmental profile. This benefit is only due to the detergent itself: even if the super concentrated container is smaller and lighter, its manufacture is more energy intensive than the regular detergent container's. Second, taking into account the real dosage used by consumers, the better environmental profile is the one of the regular detergent, for the detergent itself and for its packaging. In addition, the study conducted on users' behavior showed that they more easily sort large containers and therefore they are recycled. This result is also in favor of regular detergent packaging.

On one year, for the same service, regular laundry detergent masses used (16, 1289 kg) are slightly higher than those of the super concentrated detergent (13,028 kg). On the other hand impacts of the super concentrated are much more important in the case of equal masses. Finally, real dosage used gives a more important environmental advantage to the regular laundry package. This advantage is maintained when transport is also taken into account even if the results tend to bring the two (regular and super concentrated) performance profiles. This decreasing interest of the regular detergent must be associated to the reduction of effective masses transported in the case of super concentrated detergents with the value of 300kms of transport by truck the advantage remains to the regularly detergent. We chose the value of 300 km because it is the order of magnitude of the values displayed by several producers to represent their distribution system. Of course it must be taken into accounts that if this distance should increase (due for example to a strategy of production centralization or to reproduce the

situation of countries with lower population density) influence of the transport may afford environmental benefit to the laundry even with the super concentrated overdoses reported.
Through this article, we show that many environmental theoretical analysis can be changed if we consider reality, due to the fact that user are people with faith, fear and habits. According to our point of view, we can no longer work only on calculated environmental approach, we need to model the user behavior in eco – packaging. For example, Laitala *et al.* (2012) are interested in the changing laundry habits and they focus on clothing maintenance in order to reduce environmental impact.
We can underline that it is not always easy to combine user and eco-design. Indeed, there may be conflict between eco-design and usability as Fukuyo and Fujita's study on the fridge (Fukuyo and Fujita, 2005). Or, there may be some problem in the user acceptance with programs for sharing one single product (Alejandro and Colin, 2012). Finally, there is different way in order to facilitate the user modelisation in design, one best way nowadays seems to be (Kota et al., 2013).

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REFERENCES

Ademe & Eco-emballages. (2009). *Étude sur l'opportunité du tri et du recyclage des emballages ménagers plastiques autres que bouteilles et flacons*. Novembre 2009.
Alejandro, R.C., Colin, L.M., (2012). *A methodology for connecting User Centered Design (UCD) with Eco-design. The possibility of migration of products to services based on the user acceptance*. Work 41, 1004–1007.
Bertololini G. (1996). *Evolution des mentalités vis-à-vis des ordures ménagères / Changing attitudes with respect to household waste*. In: Revue de géographie de Lyon. Vol. 71 n°1, 1996. Risques et pollutions industiels et urbains. pp. 83-86.
Bilan effectué selon les chiffres compilés par Eurostats et rendus accessibles à l'adresse internet http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsdpc240, consultée en mars 2012.
Chapotot E., Abi Akle A., Minel S., Yannou B. (2011). *Comparative study of theoretical and real uses of eco-designed laundry detergents.* In Proccedings ICED 2011 - International Conference on Engineering Design 2011, Danemark (2011)
Conseil National de l'Emballage, (2007).*Ecorecharge, vide technique, suremballage des produits d'entretien de la maison et d'hygiène de la personne*. Url: http://www.conseil-emballage.org/Img/Publications/9.pdf
Eco-emballages. (2010). www.ecoemballages.fr, *Rapport d'activités*: Exercices 2010.
Fukuyo, K., Fujita, K., (2005). *Conflicts between eco-design and usability of refrigerators*. Ieee Computer Soc, Los Alamitos.
Kota, S., Brissaud, D. & Zwolinski, P. (2013). *A conceptual platform to view environmental performance of a product and its usage in co-design*. In Proceeding ICORD'13 – International Conference on Research into Design. India (2013).
Laitala, K., Klepp, I.G., Boks, C., 2012. *Changing laundry habits in Norway*. Int. J. Consum. Stud. 36, 228–237.
OJEU (2006). Waste. Directive 2006/12/EC, European Parliament and the Council.
Valorplast,http://www.valorplast.com/Front/evolution-tonnages-emballages-plastiques-menagersrecycles_202.php, L'évolution des tonnages d'emballages plastiques ménagers recycles.
Saouter E., van Hoof G., Feijtel T. C. J., Owens J. W. (2002). *The effect of compact formulations on the environmental profile of Northern European granular laundry detergents*. The International Journal of Life Cycle Assessment January 2002, Volume 7, Issue 1, pp 27-38.
Vargas Julian, M. (2010). *Comparison study of the reducing, reusing and recycling knowledge and habits of convential and organics food consumers*. PLOG, LTH, Lund University. Master 126 p.