COMPARATIVE STUDY OF THEORETICAL AND REAL USES OF ECO-DESIGNED LAUNDRY DETERGENTS

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ABSTRACT

Directions for use given by manufacturers of consumer products are often based on ideal conditions of use. However, each user is different and has complex user characteristics which may impact the directions of manufacturers and thus divert a product's primary functions. In this study we therefore propose examining this phenomenon of use in eco-designed laundry detergents. Initially designed to respect the environment, are they always environmentally-friendly in real conditions of use and what factors can reverse their benefits? After a state of the art in eco-designed laundry detergents and major criteria for use, we present the statistical analyses and tests which show the importance of knowing and modelling real uses so as to better design and adapt such products.

Keywords: use in eco-design, real conditions of use, user tests, modelling real uses.

1 USES & ECO-USES

1.1 Definitions

The notion of usage comes from the will to extend the notion of use as is commonly applied in a process, ie. integrating the final user in design [1]. Whilst use shows the functional dimension of tools designed by engineers, the notion of usage extends the relationship of people with technologies by focussing on the way in which they become involved with them, use them, dream about them and idealise them, by projecting their needs and wishes tainted by cultural artefacts.

Products specifications are generally too much constrain to let possibilities to adapt product to user. "Usage" is the first space to navigate in before functions which are too much precise. *Usage Coverage Model* (UCM) has been developed to better locate sets of usage that are worth to be covered by the design solution [2]. [3] explains that aim of adopting a user-centered design approach is to improve the quality of the interaction between the user and the product. Designers have to modify their design paradigm in order to include environmental, economic and societal requirements in early design process [4]. Research works focus on specifications integration related to downstream lifecycle processes [5]. Downstream processes include logistic, maintenance, use and recycling activities. Although environmental impacts evaluation tool (LifeCycle Analysis) exists, it is generally dissociated to product design. That's why, [6] work on integration of sustainability trough a function impact matrix. In this paper, we focus on use phase and environmental impacts due to interaction between users and product/service.

Products are increasingly progressing towards improved energy performance according to rationalised and directed use. Power Aware Cord and several new domestic power monitors including EnergyHub, The Energy Detective and the highly mediatised Wattson, are aimed at influencing behaviour by providing real time feedback showing users the amount of energy used by their household appliances. By making the invisible waste of energy highly visible, these devices encourage their owners to adopt more efficient habits.

The aim of the notion of eco-usage is to modellise real use and compares it to recommended use so as to determine the real impact of products so as to offer ideas for innovation [7].

In our study we focussed on a very common consumer good, used by everyone and for which both the packaging and associated messages are highly variable. The ecological impact of this product is today acknowledged and therefore deserves being studied from the user's point of view.

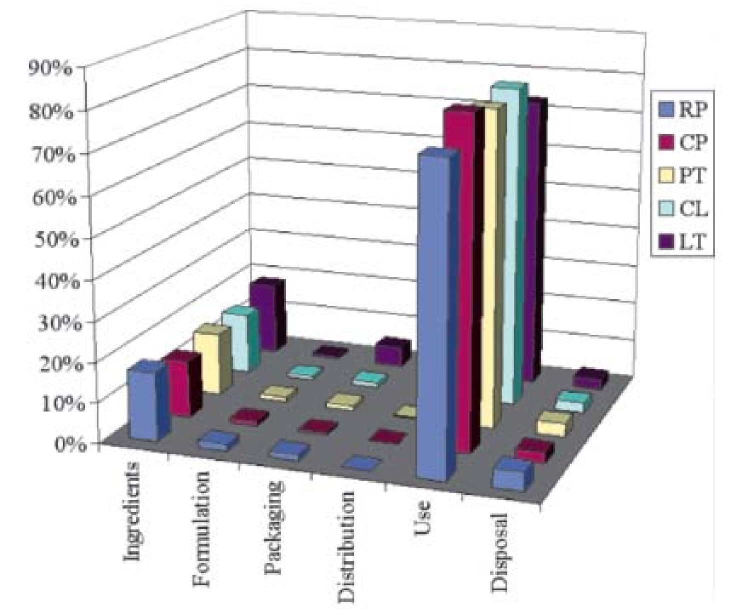
1.2 Families of laundry detergents & market shares

Today there are different types of laundry detergents on the market: refills, super-concentrates, concentrates, uni-doses (liquids and powders), classic powders and liquids. Figure 1 from observing and searching on the internet and on the field shows the distribution of families of laundry detergents according to turnover. This mapping will enable us following our comparative study to choose from amongst the most commonly used types of laundry detergent.

Figure 1. Distribution of laundry detergent categories according to turnover [8]

1.3 Why laundry detergents?

The product which we chose to study is laundry detergent. This is deliberate choice. In our research process, we want to show the potential for improvement provided by better modelling real uses of a product. We therefore logically turned our attention to a commonly used product with a high environmental impact according to its use. Figure 2 shows the percentage of impact on the environment according to the different lifecycle phases of washing power type products [9]. Laundry detergents heavily impact the environment during the use phase. This comparative study between real and theoretical use will be illustrated with common consumer products such as laundry detergents, whose dosage and characteristics of use can have a significant impact on the product's environmental performance.



RP : regular powder
CP : compact powder
PT : powder tab
CL: compact liquid
LT: liquid tab

Figure 2. Distribution of the environmental impact of laundry detergents according to lifecycle phases [9]

1.4 What is an eco-designed laundry detergent?

Amongst the families of laundry detergents, we concentrated our study on so-called "eco-designed" laundry detergents. Our aim is to demonstrate that the notion of respecting the environment is not only linked to a chemical composition which respects the environment, but is closely linked to its use.
Eco-designed laundry detergents are laundry detergents which have 2 axes of innovation in terms of eco-design: the composition and the packaging. It is necessary, on the one hand, to reduce packaging-related waste and, on the other, limit pollution due to waste water linked to the composition of detergent-based laundry detergents. In order to define which of the two axes of innovation is the most relevant, below we explain the method used to identify which of these, ie. composition and/or packaging, are behind users' purchases of eco-designed laundry detergents.

2 THE "CLOTHES WASHING" PROCESS & IMPORTANT CRITERIA

In order to identify the important criteria behind clothes washing action and therefore the use of laundry detergent, we shall firstly determine the process as well as its means of control and support. The aim of this process is to identify and define criteria which will be part of our usage tests.

2.1 The "clothes washing" process

Washing clothes with a washing machine can be considered a process. Figure 3 shows the clothes' washing process and thus enables the controls and supports which influence it to be identified and therefore the performance of the eco-designed laundry detergent. We have dissociated the physical resources from the cognitive resources that are underlined.

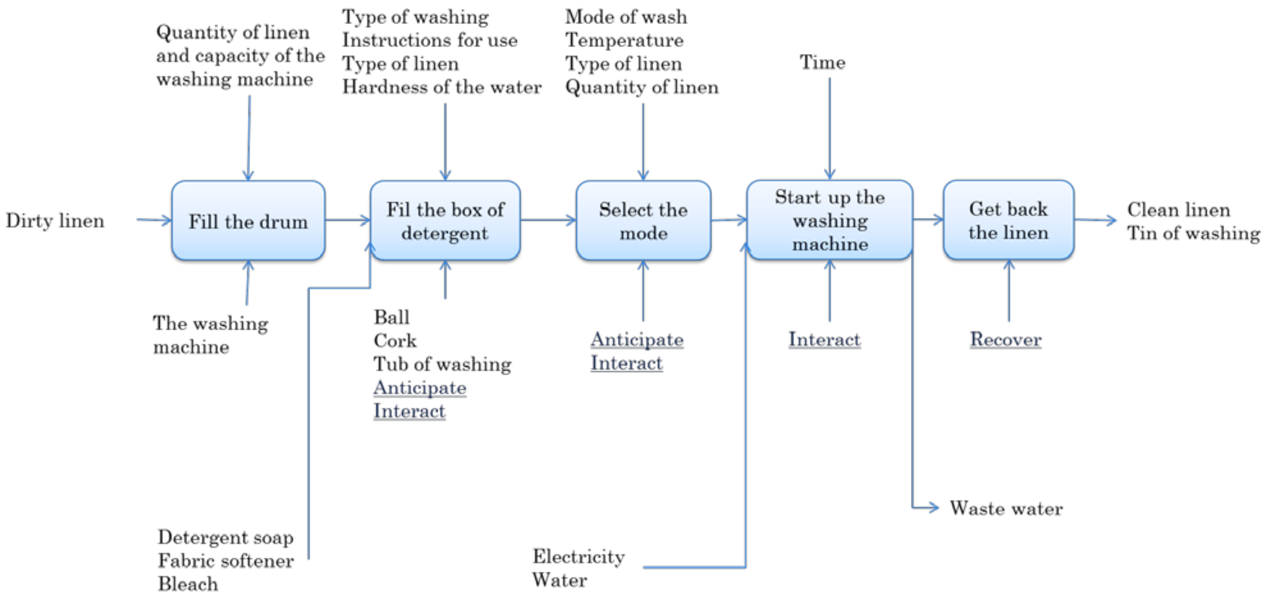


Figure 3. "Clothes washing" process

2.2 Important criteria

- **Physical means of control**

Washing machine: Here we take into account classic top or front loading washing machines (excluding machines which automatically dose laundry detergent, eg. Ariston's Hotpoint).
Doser ball: A plastic ball, usually transparent enables the laundry detergent to be dosed thanks to its graduations in ml.

- **Cognitive means of control**

Cognitive process
"The cognitive complexity of a situation is defined as the amount of cognitive resources which are required to ensure tasks are carried out with a level of performance greater than the given threshold." [10]

Table 1 shows that exist 3 types of activities during a cognitive process:

Table 1. The 3 types of activities in a cognitive process [10]

Activities	**Specific actions**
Acquisition of information of the displays, commands	Identify / read/ verify
Data processing of the displays and the commands.	Treat/ analyze/ think
Resolution of problem and decision-making.	Decide / synthetize

Within the framework of our study, users must be capable of the following:

- Identifying and verifying the type of clothes to be washed.
- Analysing and processing instructions (on the rear of the laundry detergent box)
- Deciding on the temperature, programme and dose of laundry detergent with regard to the dirtiness of the clothes.

Cognitive support for a procedure such as washing clothes must include 3 functions:

- Anticipate: Awareness of the situation (linked to the hardness of water and level of dirtiness)
- Interact: Skill and training (linked to the user's habits)
- Recover: Diagnosis (linked to a potential error occurring previously)

- **Available resources**

Type of laundry detergent: Laundry detergents include a range of ingredients aimed at removing dirt and stains on clothing and suspending them in the laundry detergent solution. Table 2 give us an outline of the basic components and their environmental impact is given below [11].

Table 2. Polluting criterion evaluation of laundry detergents and liquids component [11]

TEST METHODS		EVALUATION	
	Analysis parameters	Little polluting	Moderately polluting
Elimination	COD/COT	≥90%	≥90%
Mineralization	Evolution CO2/COT Oxygen absorption /DCO used	≥70%	≥60%
	COD/COT	≥80%	≥70%
Ecotoxicity		No R50. No R50/53	No R50/53
		≥0,5 mg/l	≥0,1mg/l
	CE50	≥50mg/l	≥10mg/l

Very polluting

Volume in %	**<0,1**	**<1**	**1 & 5**	**5 &10**	**10 & 20**	**20 & 30**	**>30**
Surfactants							
surfactants anioniques							
surfactants cationiques							
surfactants non ioniques							
Oxidizing agents							
peracides							
oxydants photochimiques							
Enzymes							

lipases							
amylases							
cellulases							
Protease							
Soothing agents							
soap							
Zeolite							
silicates							
citrates							
Polymers							
polycarboxylates							
Polyethylene glycol							
Derived of cellulose							
Other ingredients							
Perfumes							
Optical brightener							
preservative							
Disinfecting agent							

Type of clothes to be washed: There are different types of fabrics made from natural or synthetic fibres, white or coloured, which need to be washed differently. Some fabrics, such as white cotton, accept high wash temperatures better than others, such as silk, which require greater attention and therefore cold washes. We can also pay specific attention to the type of product used because white clothes prefer powders whilst colours are less suited to this type of laundry detergent which tends to leave white traces on the fabric.

Water hardness: The hardness of the water consists of calcium and magnesium ions which hinder the washing effects and iron and mangane ions which hinder bleaching. The hardness of the water neutralises bleaching agents and the polymers whose job is to suspend the dirt in the washing water.
Table 3 give an example of recommended doses according to the hardness of the water and the quantity of dirt on clothes to be washed with a classic washing liquid.

Table 3. Washing criteria according to the hardness of the water (Ariel advises)

	Little dirty	Moderately dirty	Very dirty
Low hardness	60ml	120ml	180ml
Average hardness	90ml	120ml	180ml
High hardness	90ml	150ml	210ml

To illustrate the different criteria in the "clothes washing" process, here is an example of recommendations for washing a shirt in Table 4.

We defined the context and listed the criteria of our study enabling us to present the method and dimensioning of usage tests. The aim of these tests is to compare the ideal and real use of eco-designed laundry detergents and thus show the importance of knowing and identifying these uses prior to product design. This involves demonstrating that in real conditions of use, super-concentrated eco-designed laundry detergents have a greater impact on the environment than classic laundry detergents.

Table 4. Example for washing a shirt

Example	Type of linen	Type of washing	Temperature (°C)	Hardness of the water	Level of dirt	Ideal dose
Polycoton shirt 	Synthetic	Regular liquid	40°C	average	average	**120ml**

3 DIMENSIONING THE STUDY

Eco-designed laundry detergents are those with 2 axes of innovation in terms of eco-design: the composition and packaging. Packaging related waste needs to be reduced and pollution from waste water linked to the composition of detergent-based laundry detergents needs to be limited. We once again find refills and super-concentrates (Figure 4).

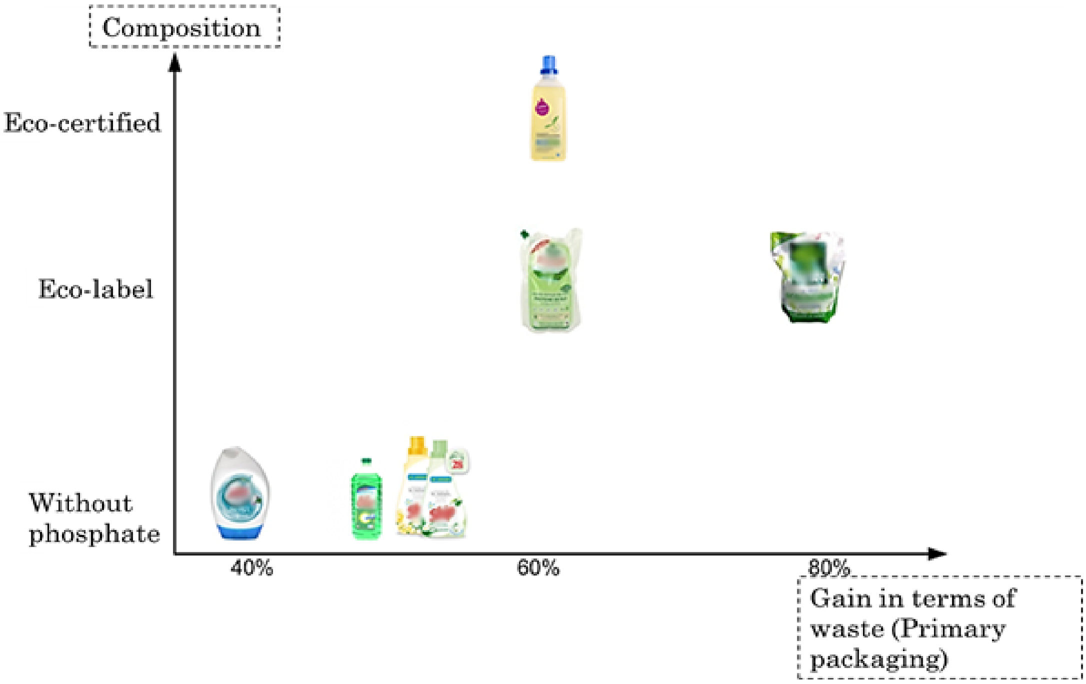


Figure 4. Distribution of concentrated laundry detergents and so-called "eco-designed" liquids according to the increase in packaging waste.

Nevertheless, laundry detergent refills, despite their eco-design, show a 20% falls in shares of sales between 1997 and 2006.

According to studies lead by [12], we note that:

Eco-refill/classic: gain of 75% in primary packaging but only 26% of the overall packaging.

Super-concentrate/classic: 57.8% gain in primary packaging compared to 53.1% of the overall packaging

After having searched for consumers using questionnaires, we namely observed amongst the different results in figure 5, that the purchasing habits of consumers are such that 2 out of 39 people use refills compared with 11 who prefer super-concentrated laundry detergents.

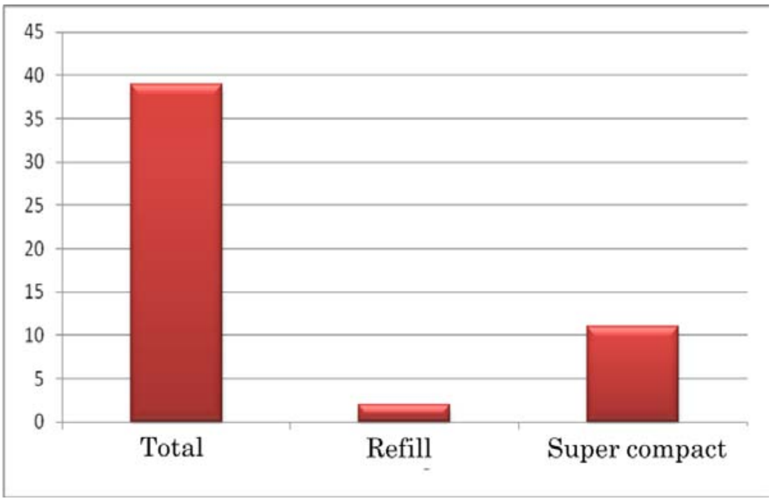


Figure 5. Number of consumers using refills and super-concentrates

In the light of these results, the study should focus on studying consumers of super-concentrated laundry detergents.

4 RESEARCH HYPOTHESES

We came up with two main hypotheses for our study. The first concerns the ecological impact of two products. We think that overdosing when using a concentrated product is more important than overdosing with a classic product. Our aim is not to discuss or condemn overdosing. We suppose that the use of concentrates is recent and that users still often misunderstand what an amount of laundry detergent actually represents since this amount is no longer suited to concentrated products.
Our second hypothesis concerns the habits of users with regard to the washing temperature. We suppose that cold washes are not yet second nature.

We therefore implemented a protocol to enable us to validate or reject our hypotheses.

5 PROTOCOL & ECOLOGICAL PROFILE: REAL & THEORETICAL USE

5.1 Panel

Characteristics of the profile:

- People resident in the Basque Country (Atlantic Pyrenees) since the tests were carried out in this region and the water there is not very hard.
- Regular users of their washing liquid: traditional or super-concentrated.
- Regularly wash clothes (approx. 3 times per week).
- No difference of age.
- Man or woman.
- With a classic top or front loading washing machine (excluding machines which automatically dose laundry detergent, eg. Ariston's Hotpoint).

Figure 6 shows the sequence of events: first a questionnaire was given to users to find out the use and number of times the machine is used each week as well as what type of clothes is washed most frequently. Then, the tester was asked to dose the laundry detergent for a machine with a capacity of 4 kg, filled with the type of clothes which the user considers average. Finally, after this step, the tester is asked to state the temperature he or she would have chosen for this type of machine (which he has just dosed).

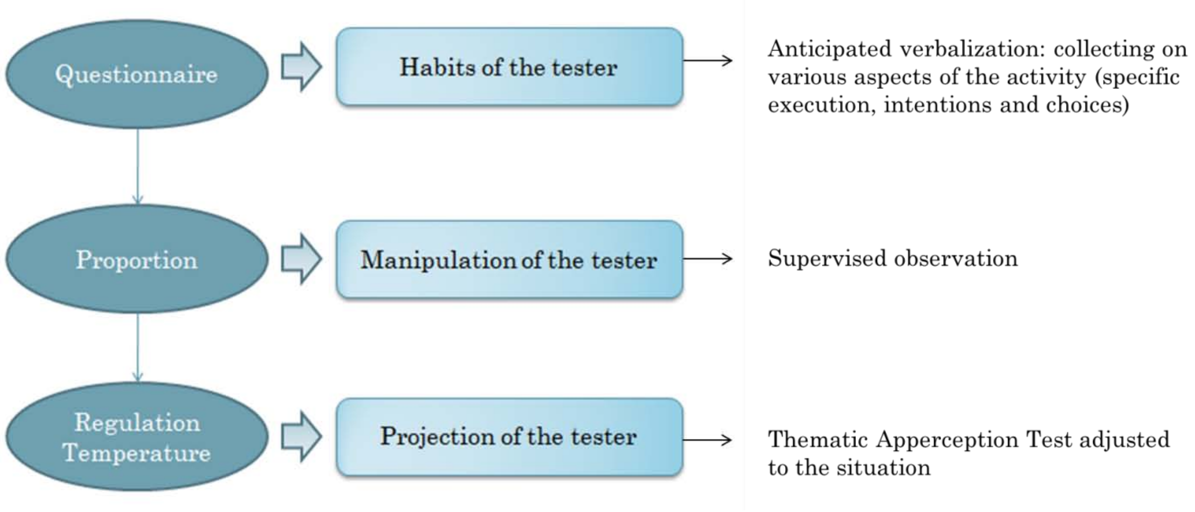


Figure 6. Usage test scenarios

5.2 Modellisation

Lifecycle phases considered:

- Extraction of materials
- Use
- End of life

Functional use of the LCA (LifeCycle Analysis):

- 4kg of clothes
- 50l of machine water
- Water not very hard (Basque Country)
- Averagely dirty clothes
- Town with 25000 inhabitants

Calculation method: CML baseline 2000 using SimaPro.
Database: EcoInvent
Error margin: 20%

5.3 Ideal conditions

Classic / Concentrated

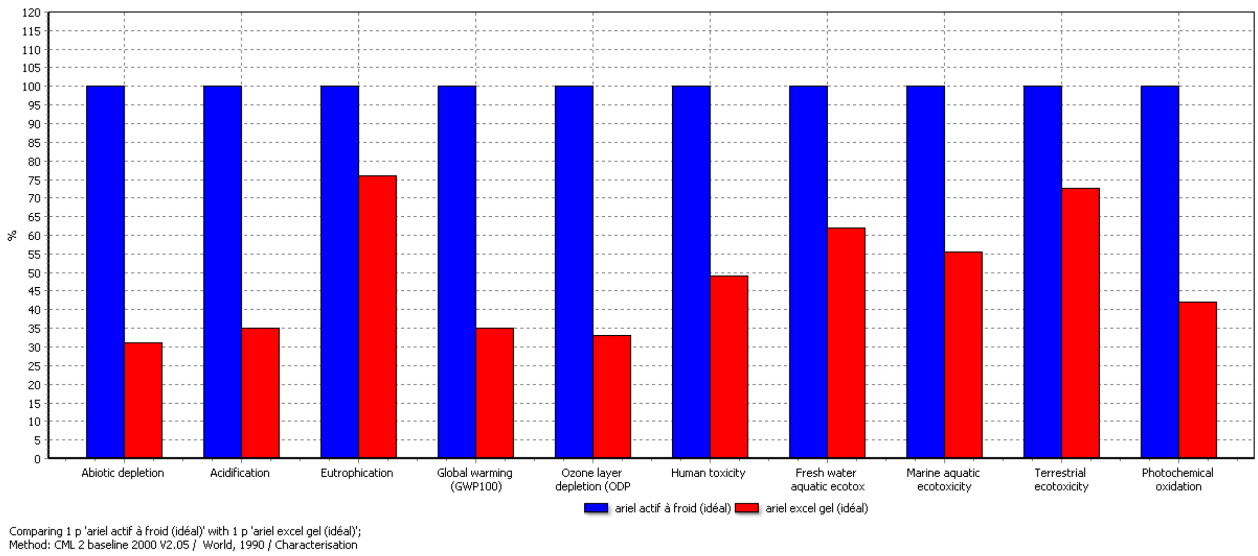


Figure 7. LifeCycle Analysis (LCA) in ideal conditions

Evaluation of the impact of the lifecycle of these two types of laundry detergent expressed here as flows in a series of distinctly identifiable indicators including, amongst others, acidification, eutrophication, human toxicity and even marine aquatic ecotoxicity. The Figure 7 above illustrates these environmental impacts and results of super-concentrated laundry detergent, expressed as percentages with regard to the impact of classic laundry detergent. The blue and red bars represent classic and super-concentrated washing powers respectively. Thus, we can note that in ideal conditions, the super-concentrated laundry detergent is more environmentally friendly than its classic counterpart.

5.4 Real conditions

In real conditions and considering the readable values, we can see that the concentrate is the most polluting, Figure 8.

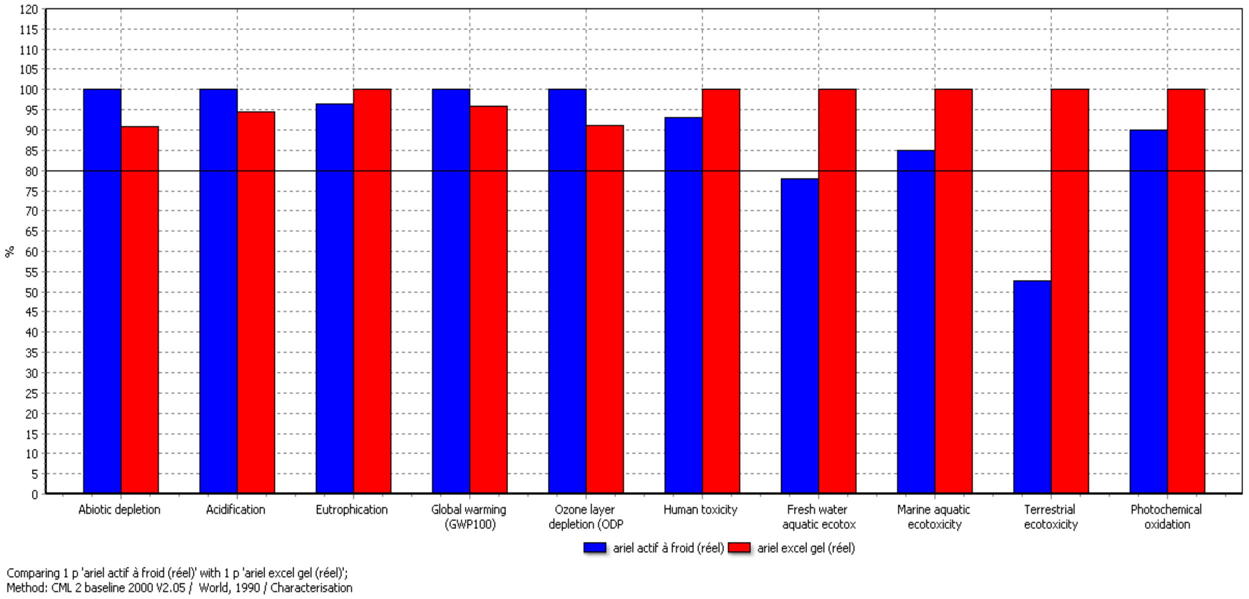


Figure 8. LifeCycle Analysis in real conditions

Since the error margin is 20% (due to the modelling software used), only the values below 80% on the graph (under the black line) are taken into account.

Even if the result is less significant that for ideal conditions, we can see that the environmental impact is reversed in real conditions of use. Using super-concentrated laundry detergents (T°C and dosage) creates a more harmful impact on the environment than using a classic laundry detergent.
The results are more contrasted than for the comparative study of the 2 products analysed in ideal conditions. Nevertheless, for both the usable environmental impact indicators, real use of the super-concentrate benefits from a better environmental performance. By respecting the 20% error margin, it is reasonable to conclude that the real use of super-concentrated laundry detergents impacts more heavily on the eco-system.

6 STATISTICAL ANALYSIS OF DATA

6.1 Influence of the panel of users and their habits

The khi-square test is used when research consists of two groups (two measurements) and the dependent variable is qualitative. This test therefore enables the frequencies of these two groups to be compared so as to infer a relation between X (here groups of users of classic and concentrated liquid detergent) and Y (answer to questions with yes or no).

Comparisons between users of classic and concentrated laundry detergents in response to the question: "have you ever read the directions for use given on the back of the detergent bottle?"

Table 4. Khi-square test results

Indicator	Groups	n	F yes	Khi-square	Value of p
Reading of the advice of use	Regular	10	4	0,18	0,671
	Super compact	8	4		

Analysing the data shows that: the group of classic laundry detergent users shows 4 out of 10 people have read the directions of use on their laundry detergent bottle, whilst 4 out of 8 people have read the directions for use for the group of concentrated laundry detergent users. khi-square = 0.18, *dl* = 1, *p* = 0.671 (Table 4).

Khi-square values and the degree of *dl* flexibility enable the value of *p* to be calculated. Since the value of *p* is higher than 0.05, this hypothesis should be accepted as nil, ie. there is no significant de distinction between the two groups. Thus, **the 2 groups of testers have the same level of "learning".**

The results enables us to state that the type of laundry detergent used does not influence answers to the question: "have you read the directions for use given on the back of your laundry detergent bottle?".

Furthermore, in the 2 groups of users, our observation shows that none of the testers read the directions given on the bottle.

6.2 Influence of dosing

Test T is used when research consists of two independent groups and the dependent variable is quantitative. This test therefore enables the average of these two groups (or measurements) to be compared so as to infer a relation between X and Y (here the two different groups of users of liquid detergent and the dosage they use).

Statistical hypotheses:

- Ho: No difference of incorrect dosage between users of classic and concentrated laundry detergents.
- H1: The incorrect dosage of users of concentrated laundry detergent > than that of classic laundry detergent users.

Comparison between users of classic and concentrated laundry detergents with regard to the volume of the dose and dosage error percentage.

Table 5. Test T results

Indicator	Groups	n	Mean	test t	Value of p
Used dose	Regular	10	76	1,274	0,221
	Super compact	8	58,75		
Percentage of proportion error	Regular	10	-36,67	-3,928	0,005
	Super compact	8	95,813		

Analysing the data in the present research shows that classic laundry detergent users add an average dose of 76 ml, whilst the dose of concentrated laundry detergent users is 58.75 ml. Test t = 1.274, *dl* = 16, *p* = 0,221 (Table 5).

Like with the khi-square test, the values of t and the degree of *dl* flexibility enable the value of *p* to be calculated. Since the value of *p* is greater than 0.05, this hypothesis should be considered null, ie. there is no significant distinction between the two groups.

Despite the difference in dosage (compared to the recommended dose), the difference between the 2 volumes (mean of doses used by the 2 groups) is not significant.

Table 5 also shows us that the percentage of error in dosage is on average -36.67% for classic users and 95.813% for concentrate users. The difference between the two groups is therefore significant (Test t = -3.928, *dl* = 16, *p* = 0.005).

6.3 Influence of temperature

Gradient test significance is used when research consists of an independent quantitative variable (X) and a dependent quantitative variable (Y). This test consequently enables a correlation coefficient to

be calculated so as to establish the existence of a link between X and Y, to measure the force or intensity of this link and to infer the existence of a correlation within the population.
Statistical hypotheses:

- H0: Relationship between T° and dose are random.
- H1: T° and Dose are inversely proportional.

Table 6: relationship between the temperature chosen by participants and the dose of laundry detergent they use

Variables	n	r	Value of p
Used temperature / Dose of used washing	18	-0,38	0,886

When the Pearson correlation coefficient is between 0.2 and 0.5 there is an average correlation link (Table 6). However the value of *p* is greater than 0.05 which means that the link is due to a coincidence.

Table 7: study reflection diagram

		Super compact	Regular
Recommended conditions of use	**Dose**	30ml	120ml
	T°	20°	40°
Real conditions of use	**Dose**	58,75ml	76ml
	T°	42,50°	38,50°

At the end of our study on real uses of laundry detergents eco-designed, Table 7 show us difference between brand use advices and real use conditions. It exist difference for 2 characteristics, temperature and dosage. Those conditions are not considered by manufacturer during laundry detergent eco-designed development. Thus, it appears a risk to bring more important impact on environment. This user test shows the importance of anticipation on product uses in order to suggest more adapt product eco-designed to users.

7 DISCUSSIONS & PROPOSALS

We shall firstly propose avenues of reflection with regard to our tests and our statistical analyses and then make our comments.

Alpha error & the value of p

For each statistical test, the alpha error and the value of p have been calculated.

The risk of committing an alpha error (first line risk) is the probability of rejecting the true null hypothesis. It should be noted that the risk of committing a beta error (second line risk) is the probability of accepting the false null hypothesis. The power of a test: p=1-beta enables a difference to be detected when one really exists. It is therefore the probability of rejecting the false null hypothesis. This power therefore enables the quality of a test to be judged. Although the power of each test was respected, ie. accepting the null hypothesis when the value of p is lower than 0.05 and, although the minimum number of participants per sample when we apply statistics in humanities (minimum = 7 participants) was also respected, it should be noted that a slightly higher number of participants per sample (=15) would have further narrowed down the value of p in the tests.

The Pearson correlation coefficient

For the influence of the temperature, the statistical test used is the gradient significance test (law of correlation). For this test, the choice of coefficient concerned the Pearson correlation coefficient because in the framework of a simple linear regression, we graphically "summarise" a cloud of points by a straight line, known as regression. Nevertheless, it would have been judicious to compare the test gradient significance test results using the Pearson coefficient with the results of the test using other correlation coefficients such as the Spearman correlation coefficient (more appropriate for repeated and ordinal variable tests) or even the Kendall correlation coefficient (for the same reasons as the Spearman coefficient but with the advantage of being able to be generalised to a partial correlation coefficient and a concordance coefficient).

***Panel**:* A narrower user panel would provide greater precision in terms of processing the results. It would have been favourable for the test to target age groups and take into consideration the tester's level of education.

***Learning**:* It would have been interesting to have a test phase with learning (for both groups) to know whether the dosage issue is not the result of the clarity of directions for use.

This means a test phase where the tester is asked to add the dose he or she considers necessary to satisfactorily wash clothes in a "full" machine. Also, after a phase of forgetting, redo a series of tests where testers are asked to read the directions for use on the back of the bottle and dose the laundry detergent after reading.

***Time**:* Greater test duration would have enabled "repeated" processing to be carried out and therefore to reduce the differences in terms of doses used by testers, eg. for a tester obtain a normal (Gaussian) law for doses used.

***Laundry detergent brands**:* Finally, during the test, it would have been more rigorous to have all the laundry detergent brands available in hypermarkets. It is possible that the packaging of certain brands would have led to a greater overdose than the packaging of other brands.

***Additives**:* It would have been relevant to note whether testers used in parallel to their laundry detergent, a softener, bleach or wash balls. In the case of bleach users may have used less laundry detergent.

Uses of this type of study

As we previously stated, analysing the results shows the possible contribution of this type of study. The panel would of course have to be extended and different statistical criteria would need to be crossed. Nevertheless, we can already identify the issues raised: how users' habits falsify the (sometimes marketing) messages with regard to the ecological nature of a product, how to innovate so as not to create a niche, but rather with the aim of designing an efficient, sustainable and ecologically virtuous product. We campaign for usage to be modellised and taken into account to make the product's design responsible too.

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