TECHNICAL BULLETIN - PLASTICS BAGS AND THEIR ENVIRONMENTAL IMPACT

1 Introduction.

In recent years there has been an increase in the debate about the environmental impact of the use of plastic bags. This concern has led some governments to create laws that restrict or even prohibit the use of these types of bags.

The main arguments against the use of plastic bags are: the problem of the adequate final disposal of the bags and the fact that they can last for many years before degrading, which has generated, in some sectors of society, the idea that the use of this type of bag should be prohibited, but, on the other hand, the big question arises: what type of bags should we use instead of polyethylene (PE)?

Some US states have adopted some type of ban or tax on the use of plastic bags, while in Europe the possibility of banning the use of non-biodegradable plastic bags throughout the European Community is being studied. In the Asian Continent, there are also countries, such as China and the Philippines, that have banned plastic bags, as well as in Latin America, represented by Mexico and Argentina, who already have laws that prohibit the use of non-biodegradable plastic bags. . However, in many of these laws, the definition of biodegradation does not follow international standards, it is confused with degradation due to environmental exposure or it is not even presented.

Some countries, such as France, Australia and the United Kingdom, have financed studies that determine the environmental impact of the different options available to replace disposable high-density polyethylene (HDPE) bags.

The most outstanding conclusions of these studies are: a) The environmental impact of all types of bags is dominated by the use of resources and the stage of production, while transportation, secondary use and final disposal have a minimal impact. b) Regardless of the type of bag used, the key to reduce the environmental impact is in reusing the bag as many times as possible, either as a supermarket bag or any other secondary use.

2 Life Cycle Analysis.

The Life Cycle Analysis is a standardized method that allows comparing the environmental impact of the production, use and disposal of a product or some service provided throughout its cycle of use. That is to say, the Life Cycle Analysis identifies the use of materials and energy, emissions and waste flow of the product, service or process that it produces during its entire cycle of use, to determine its performance in terms of impact on the environment.

Some of the stages in the use cycle of a bag that are considered in a life cycle analysis are:

Extraction and production of the raw material: either the extraction of natural resources, such as gas or planting, and the process that then leads to the production of the raw material such as: polyethylene, polypropylene, paper, cotton, starch/polyester.

Packaging: both the packaging of the raw material and the bags are also taken into account as part of the environmental impact.

Bag production process: the energy used in the transformation of the resin into bags is considered in the life cycle analysis.

Transport: The transport of the raw material to the transformer, of the finished product, already packaged, from the transformer to its final destination (taking into account all the intermediate warehouses) and the garbage collection system are considered.

Final disposition: bag waste management should be considered in this method. There are several methods for waste management, among which are: landfills, incineration, mechanical recycling and composting (allowing its decomposition by the action of bacterial and microbial agents present in the soil).

Recycled and reused: is included within the life cycle to model the impact of secondary use, recycling and the raw material that is not used when recycling the bags.

3 Materials used to make bags.

Among the most used materials for the manufacture of bags are:

High density polyethylene (HDPE): They are the most used bags in supermarkets. They are light and with a very low thickness.

HDPE with pro-degrading additive: this type of bag includes an additive that promotes accelerated degradation of the polyethylene. They are commonly called ecological bags and even biodegradable bags; this last term is incorrect in this context.

Low density polyethylene (LDPE): these bags are thicker and therefore are not transparent. They are generally used in places such as hardware stores, where the weight of the products is greater, or their shape requires tear resistance that the HDPE bag cannot provide.

Polypropylene (non-woven): This bag is thicker and therefore more resistant and can be reused many times.

Polypropylene (woven): These bags are woven and generally have an insert that shapes them. These bags can and should be reused many times due to their great strength.

Cotton fabric: cotton woven bag that can and should be reused many times.

Paper: Bags used by some stores to transport few low weight objects (the most common example is bread). If they get wet they lose their resistance and break easily.

Biopolymers: these plastic bags are generally composed of a polymer manufactured from some made from some starch extracted from the corn, potato or wheat, for example. A bag made of Biopolymers no necessarily biodegradabe: for example, the polyethylene obtained through the polymerization of ethylene distilled from sugar cane is essentially the same polyethylene obtained from ethylene distilled from natural gas associated with petroleum, although its environmental impact is less.

4 Evaluation of the environmental impact of plastic bags.

The environmental impact produced by making a bag takes into account all the stages of the life cycle described in section 2.

To adequately assess the environmental impact caused by the production of the bags, various categories of pollution and/or contribution to global warming are quantified.

The categories commonly considered and found in some studies, such as those carried out by the United Kingdom Environment Agency: "Analysis of the life cycle of supermarket bags"(1) and "Analysis of the environmental impact of oxo-degradable plastics during their usage cycle"(2); and those carried out in Australia: "Plastic shopping bags - Analysis of taxes and the environmental impact(3) and "The impact of the bags degradable in Australia"(4) are:

- **Global warming potential:** it is a measure of how much gas (which produces the greenhouse effect such as CO_2, methane, nitrous oxide) of a given mass contributes to global warming. It is measured in kilograms of CO_2 equivalents.
- **Abiotic depletion:** This category refers to the consumption and, therefore, depletion of non-living resources, such as: fossil fuels, minerals, clay, among others. It is measured in kilogram equivalents of antimony (Sb).
- **Photochemical oxidation:** is the measure of waste that they potentially create

photo-oxidants. The formation of photochemical oxidant smog (smog) produced by the reaction of photooxidants with UV radiation causes ozone in the troposphere. Photochemical oxidation is measured in equivalents of ethylene.

- **Eutrophication:** It consists of the addition of nutrients to the soil or water that causes an increase in biomass, altering the ecological balance, favoring the growth of some forms of life and harming others. Nitrogen and phosphorus are two of the nutrients with the greatest influence on eutrophication. Eutrophication is measured in terms of phosphate equivalents (PO_4^{3-})
- **Acidification:** results from the deposition of acids, which causes a reduction in pH, mineral content and increases the concentrations of potentially toxic elements in the soil. The biggest pollutants in this category are: SO_2, NOx, HCL and NH_3. Acidification is measured in terms of SO_2 equivalents.
- **Toxicity:** It is the degree to which a substance is capable of causing disease or harm to an exposed organism. Toxicity is measured in terms of di-chlorobenzene equivalence.

5 Environmental impact of plastic bags.

In the study carried out in the United Kingdom, during the years 2006 and 2007, entitled "Analysis of the life cycle of supermarket bags" (1), which was financed and promoted by the Environmental Agency of the Government of England and Wales, an entity independent public, bags made from the materials described in the section 3, excluding biopolymers and woven polypropylene bags.

In this study, a Life Cycle Analysis was performed. Life of the different types of bags. To do this, it defined the number of bags that a typical Briton uses monthly for their purchases at the supermarket. This number was calculated for each of the types of bags, taking into account the capacity of each bag and the weight it supports, as well as the shopping habits of the British.

Table 1 shows the basic data for each of the types of bags commonly found in UK supermarkets.

Table 1. Data of the types of bags studied. Stock referenced securities

Bag type	Volume (l)	Weigh (g)	Items to pack
HDPE	19,1	8,12	5,88
PEAD w/prodegradant	19,1	8,27	5,88
LDPE	21,5	34,94	7,96
PP	19,8	115,83	7,30
Polyester-Starch	19,1	16,49	5,88
Pape	20,1	55,20	7,43
Cotton	28,7	183,11	10,59

From the data shown in Table 1, and considering that each Briton on average buys about 483 items, the monthly consumption of bags for each type was obtained through surveys and consultations with the various product suppliers.

For the calculation of each of the environmental impact categories described in section 4, each of the stages of the life cycle of a bag described in section 2 were used.

The results obtained in the study by the Environmental Agency of England and Wales (1) are shown below for each of the categories described in section 4.

5.1 Global warming and contribution of each stage of the life cycle on the total potential.

Figure 1 shows the global warming potential (GWP) for each of the bag types. These values were obtained considering each of the stages of the life cycle of a bag.

The result obtained for the bag made of cotton is not shown as its GWP is more than 10 times higher than that of any other type of bag.

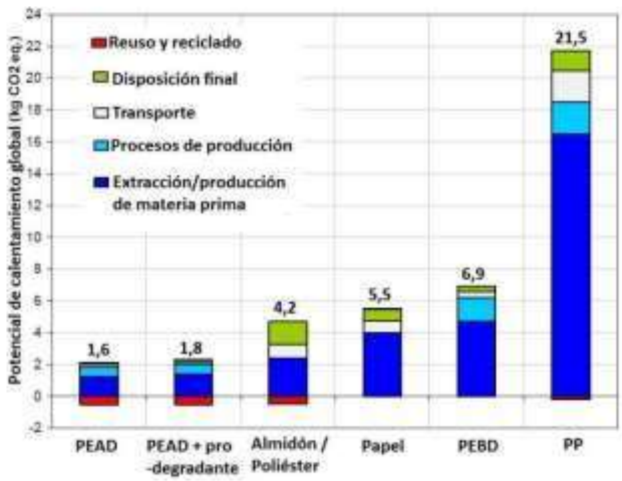

Figure 1. Global warming potential of each type of bag.

The PCG is mostly influenced by the stage of extraction and production of the raw material, representing 54 and 80% of the total PCG.

The contribution for the transport of the bags and raw material is defined mainly by the distance from where it is transported. It also depends on the type of transport used. In the case of Great Britain, HDPE, PP and HDPE with pro-degradant is transported from the Middle East, while the mixture of starch and polyester is transported by land from Italy and Norway. Note that these are long routes, so one way to reduce the environmental impact is by promoting local production.

The final disposal method influences between 0.2 and 33% of the total PCG. PP and HDPE bags are incinerated in the UK which contributes between 5 and 7% of the total GWP, while starch and polyester bags are disposed of in landfill which has a greater impact on global warming (18-29%).

It is important to note **that total GWP is directly related to the amount of material needed to produce each bag (bag weight).** The greater the weight per bag, the greater the impact on global warming since more energy is consumed for its production and extraction, as well as its transport and final disposal also have a greater impact.

5.2 Environmental impact of alternative materials to HDPE for the manufacture of bags.

Figure 2 shows the comparison of the environmental impact in different categories (described in section 2) of various materials used for the manufacture of bags: HDPE, HDPE with pro-degradant, mixture of starch and polyester and LDPE. According to the work carried out by the United Kingdom Environmental Agency (1), these materials are the ones that present the least environmental impact when they are not reused. **HDPE is the material with the least environmental impact when compared without considering the reuse of any bag**, for this reason the values of each material were normalized to that of HDPE as a base and with a value of 100 for each category corresponding to that of HDPE.

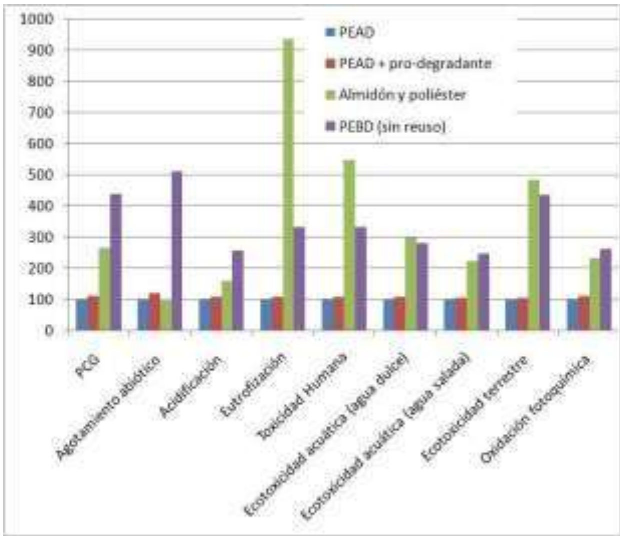

Figure 2. Environmental impact of various types of material used for the manufacture of bags.

Figure 3 shows the comparison in the environmental impact produced by bags made of PEAD, paper and PP. This graph shows the values normalized to 100 in each category, which correspond to the value of the impact of the use of PEAD. The results for the cotton bag are not shown because its impact is much greater than the rest of the materials.

The first point that stands out is that, contrary to what is expected, **the environmental impact of HDPE bags is less than that of HDPE bags with a pro-degradant**. This result is due to the higher weight of the HDPE bag with pro-degradant and a slight increase in abiotic depletion due to the use of stearic acid in the manufacture of the pro-degradant.

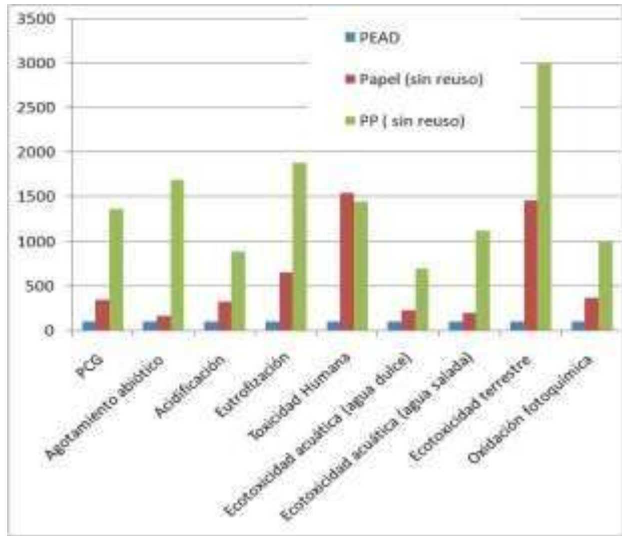

Figure 3. Environmental impact of various types of material used for the manufacture of bags.

The study carried out by the Environmental Aency of the United Kingdom [1] concludes that <u>HDPE bags are the ones[1] that have the least environmental impact</u> among the different alternatives studied. This is concluded assuming that none of the different types of bags is reused; For this reason, in this work the number of times that each type of bag has to be reused in order to achieve a lower environmental impact than that caused by the PEAD bag was calculated, giving the following results:

- Paper bag - 4 times,
- LDPE bag - 5 times,
- PP bag - 14 times
- Cotton bag - 173 times

These numbers represent the number of times that each of the mentioned bags must be used **to equa**l the environmental impact of non-reused HDPE plastic bags. It is important to note that HDPE bags are typically reused at least once as waste bags, so this comparison is conservative.

Figure 4 shows the environmental impact in the different categories analyzed in the British study (1), considering that they are reused the number of times necessary to have a lower environmental impact than the HDPE bag. Once more, the values were normalized to 100, based on the value of the PEAD bag in each of the categories analyzed.

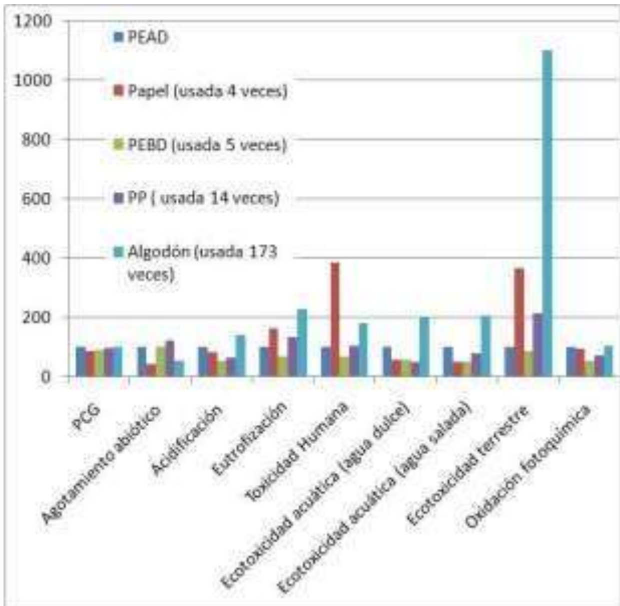

Figure 4. Environmental impact of materials with the necessary reuse to reduce the environmental impact of PEAD.

The performance of the LDPE bag stands out, which must be reused only 5 times to match the environmental performance of the HDPE bag in all categories, which is easily possible due to the resistance of this type of bag, while in the case of the paper bag, which is not as resistant, must be reused 4 times to match the environmental performance of the HDPE bag, which is more difficult to achieve and, even so, the paper bag has greater human toxicity and terrestrial, as well as increased eutrophication**.**

The cotton bag, being reused 173 times, has less impact than the HDPE bag in only 3 of the 9 categories studied; while in the case of the PP bag, the impact is reduced with respect to HDPE bags in 6 of the 9 categories considered.

It is important to note that the results obtained by the UK Environment Agency were during the period 2006-2007 according to: a) the purchasing habits of the British for that time, b) the data corresponding to that time and region regarding the materials used and from where they were imported, processed and how they were transported to the final destination of use, c) the final disposal techniques used apply to the practices carried out in that period for each type of material (incineration, sanitary landfill or other) were also considered according to the practices carried out in that country for the period that the study lasted.

Even when that study takes into account the impacts of transport, use and disposal in the UK, the results obtained suggest that similar conclusions should be drawn in other countries. However, each country must be analyzed individually.

In Venezuela, for example, polyethylene and polypropylene are produced locally, while in the United Kingdom they are imported from the Middle East. This would reduce the environmental impact of HDPE, LDPE and PP bags in Venezuela, however, the final disposal of these types of materials is in sanitary landfills, which has a greater environmental impact than controlled incineration, which is the method used in the United Kingdom.

6 Traditional plastic bag (HDPE) vs. "biodegradable bag".

Self-styled "biodegradable" plastic bags are commonly mentioned as an alternative to solve the problem of disposing of traditional plastic bags that persist without degrading for a long period of time. However, there are several points that need to be considered:

6.1 Biodegradable, oxo-degradable and compostable bags.

There are important differences between the terms "biodegradable", "oxo-degradable" and "compostable", which are commonly used to classify the type of degradation that a bag undergoes.

Biodegradation: Biodegradation: It is a biological process that occurs after the plastic has degraded. According to the CEN 13432 and ASTM D 6400-04 standards, a biodegradable plastic is one in which degradation results in fragments of sufficient low molecular weight for its processing into biomass by microorganisms, such as: bacteria, fungi and algae, activity that must occur in 60% or more of the product's weight in less than 6 months. In particular, the CEN 13432 standard is a very complete compendium to determine the biodegradation characteristics of a package. Tests carried out on films added with pro-degrading products at different rates of addition, even higher than those recommended, showed a loss of molecular weights similar to that of the conventional HDPE bag attacked by photodegradation (environmental exposure

Oxo-degradation: is a process in which a plastic undergoes oxidative degradation, which is a series of complex chemical reactions where long chains of polyethylene molecules break into shorter chains due to the action of oxygen, ultraviolet light and/or heat (with a molecular weight less than 5000 according to ASTM D 6954-04, specific for this type of degradation). It is important to note that a conventional polymer or one with additives to be oxo-degradable cannot be considered biodegradable unless it complies with the corresponding regulations (transformation into biomass in a given period and verification of the non-toxicity of the remaining waste).

A **compostable plastic** is defined in the ASTM D 6400 standard as: "A plastic that undergoes degradation due to a biological process producing CO2, water, inorganic compounds and biomass, at a rate consistent with other known compostable materials, without leaving visible, distinguishable evidence or toxic waste".

It is important to identify the degradation mechanism of the bag material in order to dispose of it correctly and reduce its impact. An example of this is that oxo-degradable bags are not compostable. In fact, an oxo-degradable bag that is disposed of in an anaerobic environment could increase its environmental impact compared to a conventional bag.

Therefore, labeling bags with pro-degrading additives as "biodegradable" bags may lead consumers to believe that the bag is 100% biodegradable and you can freely dispose of it in landfills or anywhere else, which can increase environmental pollution [(2)].

6.2 Life cycle analysis of biodegradable bags, PEAD and alternatives.

An Australian study, carried out jointly by ExcelPlas Australia, RMIT Center for Design and the Nolan-ITU institute, directed to the Department of the Environment of that country and published in 2003 (4), carried out a Life Cycle Assessment for various alternatives of degradable materials for bags and compared them with traditionally used materials such as HDPE, LDPE, PP and paper.

Among the degradable materials considered in the study as an alternative for the manufacture of bags are:

- **Master-Bi™ (Italy):** thermoplastic starch derived from corn, potato or wheat, mixed with polyester (PLA or PCL)
- **Earthstrenght (Lloyd Brooks)** thermoplastic starch derived from tapioca, corn, potato or wheat, mixed with polyethylene.
- **EcoFlex™ (BASF):** aliphatic/aromatic copolyester of adipic acid.
- **Bionelle (Showa Highpolymer, Japan):** polybutylene succinate (PBS).
- **PEAD+EPI®:** high-density polyethylene plus pro-degrading additive.

The data used for the Life Cycle Analysis, such as: consumer habits (weekly purchases, number of items purchased and use of bags), origin and disposition of each type of bag used, among others, were considered for the period from 2002.

Figure 5 shows the results obtained in this study, specifically the global warming potential, broken down by greenhouse gas emissions.

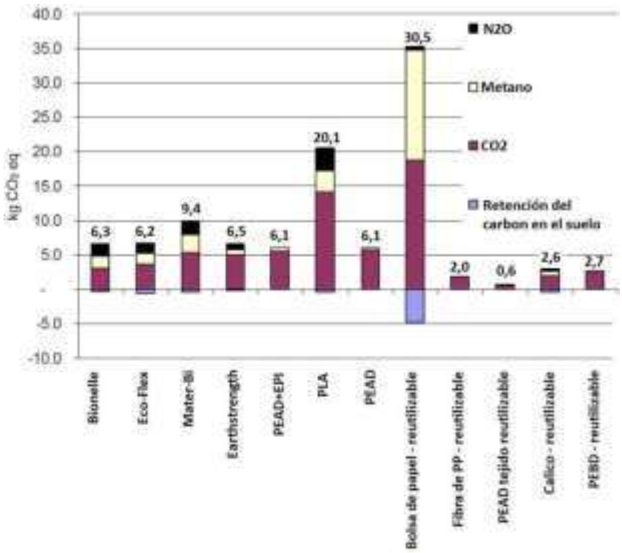

Figure 5. Greenhouse gas emissions from the different types of bags studied [4].

Greenhouse gas emissions are dominated by CO2 emissions due to the use of electricity and the transportation of raw materials and products. Then there are the methane emissions that occur during material degradation under anaerobic conditions. Nitrous oxide (N2O) is emitted due to the fertilizers used on crops and crops. Methane has 21 times more greenhouse potential than CO2, while N2O has 310 times more potential than CO2.

The results of the Australian study shown in Figure 5 indicate that the reusable HDPE bag is the one that produces the least amount of greenhouse gases; while the paper bag is the one that generates the greatest greenhouse effect in its life cycle.

PEAD with a pro-degradant is the material that has the least potential for climate change among the degradable materials and this, in turn, has the same effect greenhouse than the HDPE bag without the additive.

On the other hand, degradable bags have a higher global warming potential compared to reusable bags and HDPE without reuse, due to methane emissions during their disposal in landfills and the N_2O emitted by the fertilizers used in planting and starch cultivation.

Degradable materials based on starch-polymer mixtures, due to the approximately 50% reduction in the use of fossil resources, have between 25% and 75% less abiotic depletion than HDPE or PLA bags, while in this category the highest consumption of resources, has the paper bag. Reusable bags have a lower impact in this category compared to non-reusable HDPE bags.

The PLA bag is the one that has the greatest impact on eutrophication, followed by bags made from starch-polymer mixtures, and this is due to the application of fertilizers on their crops. The impact of HDPE, LDPE and PP bags is insignificant compared to that of other bags.

At the same time, this study considered that an average consumer would use 520 disposable bags per year made of any of the following materials: starch-polyester blends, paper, HDPE+EPI® or HDPE; while if they are reused, the calculated average use of bags per year would be: 4.15 of woven PP (two years of use of each bag); 1.65 PEAD woven bags (two years of use for each bag, which, due to its greater capacity, requires fewer PP woven bags); 26 from LDPE; and 9.1 calico (woven cotton).

The reuse of woven PP, woven HDPE, calico and woven LDPE bags means that these bags have a lower greenhouse effect compared to biodegradable and single-use bags such as HDPE and paper. This is consistent with the findings of the British study (1) summarized in section 5.2.

Regarding aesthetic aspects and marine biodiversity (which refers to the potential for small parts of these bags to be ingested or become entangled in marine fauna), in the final disposal of waste, bags made of non-degradable materials they have a much greater impact, although the reuse of the bags drastically reduces this impact.

On the other hand, a study recently reviewed by some journalistic works in the world such as the BBC (England) [5], El Nacional (Venezuela) [6], FoxNews, CNN and Internet pages on ecological issues, indicate that the rapid Decomposition of biodegradable plastics can be counterproductive due to the rapid generation of methane, which is a gas whose greenhouse effect is much greater than that of CO_2.

It is important to highlight that the studies carried out by several countries coincide in determining the low toxicity of plastic bags compared to their alternatives. This indicates that the use of this type of bag should not be prohibited, since bags with alternative materials have a greater environmental impact unless they are reused many times, which is to leave the responsibility of minimizing the environmental impact in the hands of the consumer. something that has already proven to be ineffective at the point of the correct final disposal of the bags. Therefore, what must be achieved is to promote the recycling and reuse of plastic bags, where there have been interesting initiatives in many countries of the world that can be followed.

7 Summary

Several independent studies in different countries, and generally financed by public entities, in order to determine which is the best alternative to replace the use of PE in the manufacture of bags to reduce the environmental impact, have concluded that when the complete cycle is analyzed life of a bag and none of the options is considered reusable, the HDPE bag has the least environmental impact, largely due to the low amount of material and energy needed to produce each bag.

The studies reviewed so far indicate that reusable bags have the lowest environmental impact among all the options studied, although the rate of reuse required to match the environmental impact of the HDPE bag is high, appearing unrealistic. This impact depends on the consumer, who must reuse each type of bag a minimum number of times so that less pollution actually occurs.

Contrary to what might be expected, the use of pro-degrading additives in the bags produces a greater environmental impact than the traditional bag without this additive. Additionally, the labeling of oxo-degradable bags as "biodegradable" or "ecological" can lead the consumer to a bad concept and dispose of it improperly, thus increasing its environmental impact.

The best action that can be taken by the user is to reuse plastic bags, whatever the material, as many times as possible. This ensures a much greater decrease in environmental pollution.

The ban on the use of bags made of polyethylene can contribute to opting for much less sustainable and impractical alternatives. The use of consumer awareness campaigns can be more effective and thus contribute to a real decrease in environmental impact.

8 Bibliographic references

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