

# LCM approach in retailing sector of cleaning products in Brazil

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## Abstract

RL Higiene operates in the retail market for professional cleaning. In order to establish a new business strategy the company structured a technical partnership with one of its suppliers, and the Group of Pollution Prevention from University of Sao Paulo in order to perform a comparison, using LCA, for two of the most important products in the portfolio of floors and decks cleaning, HD201 and HD410. The analysis was performed on two levels: the first level generated results for the company reinforce its image in market, which can be converted into advantage over the competition. The second level of analysis provided data for definition of its managing policy of the business, which definitely incorporated the environmental variable.

## 1 Introduction

Incorporating environmental factors into the management business has become, step by step, customary practice for the Brazilian companies. This behavior can particularly be observed in companies from services sector. That's the case of an organization of retail house cleaning supplies and household cleaning products sector. RL Higiene (RL-H) operates in the retail market for professional cleaning since 1977. With the experience the company changed its way of interacting with the market. RL-H no longer sells hygiene products for commercial and industrial environments, and started to offer solutions based on the concept of sustainable cleaning. I.e.: RL-H began installing sanitary procedures that meet both expectations of environmental sanitation and health protection of users from these areas, as well as the operators of cleaning.

This philosophy also and necessarily includes rational use of material resources and minimal generation of emissions to nature. The idea behind this approach is to make cleaning more sustainable every day. With the characteristics and attributes that can better meet the needs of its customers, RL-H develops partnerships with a wide variety of manufacturers in order to maintain quality and continuity of supply in the long term. This style of being and acting accumulated nowadays relationships that resulted in monthly assistance to over 900 clients. In order to remain among the leaders of an agile and competitive market like that one occupied by small companies in the service sector of cleaning, RL-H adopted some organizational actions. One of them consists in creating and maintaining an executive committee dedicated to assess trends and strategies in the fields of innovation and sustainability on social, economic and environmental dimensions. The first step of committee within action limits of environmental sustainability was to lead the development of Greenhouse Gas Inventory - Scope 3, based on the methodological approach provided by GHG Protocol Initiative [1].

This effort was carried out in order to meet two objectives: to provide business with information to that could be used to build effective strategies to manage and reduce GHG emissions; and, to provide information to facilitate participation of RL-H in voluntary and mandatory GHG programs. From the results generated by the study, RL-H realized that the operations that it own, or control, exercised little influence in terms Climate Change potential.

In this frame, the company decided to change the focus of its management and began to incorporate a vision based on Life Cycle Thinking. This approach makes life cycle assessment (LCA) a strategic tool for determining the environmental performance of products it sells. Concerned with its image in the market – widely demanding for environmental preservation – RL-H decided to establish a program to improve the environmental performance of products it distributes. The program was structured as a technical partnership involving the retailer itself, the manufacturers of cleaning products, and the Group for the Prevention of Pollution (GP2) of the Polytechnic University of São Paulo. The first project of the program comprehended a comparison for two of the most important products in the portfolio of floors and decks cleaning, HD201 and HD410, performed by LCA approach. From these results, RL-H intends to improve its business management and thus, give environmental sustainability a more important role.

Regarding its downstream relations – with consumer – the company's strategy is based on providing information about resource consumption and emissions from their products. Moreover, the relationship with suppliers - upstream, RL-H seeks to environmental issues become part of its decision-making process.

In order to support so many different contexts, the environmental comparison of HD410 and HD201 was performed at two different levels in terms of addressing environmental impact indicators.

To meet to the objective of providing market information more accessible and known indicators as Emissions of Greenhouse Gases (GHG), Water Consumption and Ecological Footprint were employed. On the other hand to achieve the second strategic aim of the company a set of rigorous and analytical indicators, provided by CML 2000 baseline's method was used to establish the environmental impacts magnitude of both products.

## **2 Products features and processing technology**

### ***2.1 Higindoor 410 - HD410***

Higindoor 410 (HD410) is a neutral detergent with about 30% assets employed in cold floors cleaning, especially those one treated by polymeric base. HD410 is composed of ionic and anionic surfactants, and water-soluble solvents, which gives to it an acidity level as pH of 6-8. HD410's processing technology is quite single. It consists of a batch process with mechanical stirring for complete mixing, which occurs at 20°C of temperature [2]. HD410 is produced from different reagents. Among these can be highlighted the Sodium dodecylbenzenesulfonate (LAS), an organic compound with the general formula  $C_{12}H_{25}C_6H_4SO_3Na$ . LAS is a colorless salt, usually produced as a mixture of sulfonates with useful properties as a surfactant [3]. Hydrated ethylic alcohol and water are used as solvents in the formulation. In order to make pH adjustment, is usual to added to each batch some alkaline products as triethanolamine and sodium hydroxide (NaOH) - generated by the technological routes of mercury cell, diaphragm and membrane. The product also is composed of balanced system of an oxide amine and an anti foaming solution. As additives are used EDTA, aqueous iso-thiazolinone, hydrogen peroxide, and yellow dye. Batch reactor cleaning up is performed using water under pressure in order to reduce it consumption. Wastewater is reused to the next batch, avoiding process effluent generation. The product is packaged at its higher level of concentration in containers of 2 liter volume. However, HD410 can be diluted by the consumer in accordance with its interest and need.

## ***2.2 Higindoor 201 - HD201***

Higindoor 201 (HD201) is a multipurpose cleaner professional applicable to different washable surfaces such as floors, walls, doors, glass, metal furniture, plastics and sanitary appliances, among others. As HD410 this product has about 30% concentration of active mainly from organic origin. As its homologous, the HD201 is produced in batch reactors with mechanical stirring, and at environment temperature [2]. Its main components are respectively: LAS and sodium laureth sulfate (SLES). SLES is a surfactant synthesized from renewable tillage of palm oil, with general formula  $\text{CH}_3(\text{CH}_2)_{10}\text{CH}_2(\text{OCH}_2\text{CH}_2)_n\text{OSO}_3\text{Na}$ , that is responsible for the main foaming properties of the product [4]. Water and the 2-Butoxyethanol – a colorless liquid, derivate from ethylene glycol and formula  $\text{C}_4\text{H}_9\text{OC}_2\text{H}_4\text{OH}$  [5] – are commonly used as solvents. Alkaline triethanolamine and sodium hydroxide are used to make pH control during the processing. HD201 also receives some finishing additives like Ethylene Diamine Tetra-acetic Acid (EDTA), isopropyl alcohol, essence of lemon and blue dye. Product is also packaged in high in 2L containers and, it can also be diluted at different concentration.

## **3 Life cycle assessment of HD410 and HD201**

### ***3.1 Goal definition and scope***

The goal of this study was defined as the comparison of the environmental performance of cleaning products HD410 and HD201 by applying the approach of LCA. As such, there was used of LCA methodology described in standards ABNT NBR ISO 14040 and 14044 [6, 7].

Regarding scope definition were established the following technical requirements:

Product system: dilute solutions in water of HD410 (1:100) and HD201 (1:66.7)

Function: to keep clean the tile floor of an industrial cafeteria in business center.

The concept of cleanliness is established at Normative [8]. It is considered 'clean' any polished and treated surface, which is disinfected, and whose average reflectance degree values (IRV) - measured in basis (%) - sampled in at least 75% of its total area, is equal or greater to 85%. To confirm this condition, there were performed Reflectance Degree measurement for both of the cases.

Functional unit: to keep it clean daily 85m<sup>2</sup> tile floor of an industrial cafeteria in business center.

Product's technical performance: empirical test had determined an average consumption to the HD 410 of 60mL for cleaning 1m<sup>2</sup> tile floor under study conditions. The HD201 presented equivalent performance to being consumed at a rate of 60.5mL / m<sup>2</sup> [9].

Reference flow: as the area under analysis is cleaned up twice a day, it will be necessary to consume respectively 10.2L of HD410 and 10.3L of HD201 in order to attend the function defined for the study.

System boundaries: the product systems' boundaries for both cleaning agents covered the following unit processes: manufacturing of the good itself (HD410 and HD201); obtaining of reactants and intermediate materials used in each of the formulations; and, the use step of each life cycle. Besides, it were considered the environmental loads associated to utilities employed in the product systems: generation and transmission of electricity; water collection, treatment and distribution, either for process, or dilution; and, wastewater treatment generated due to products use). Activities of transportation and storage were also included.

Data Quality: environmental loads modeling for unit processes of manufacturing and use of HD410 e HD201 were performed by primary data. Besides, for the great part of reactants production processes, and for all of the stages of storage and transportation were also collected field data.

On the other hand, in order to build up inventories for electricity production and transport; water, and wastewater treatments, were used secondary data, collected from technical literature, or estimated from material and energy balance.

Exclusion criteria: it were excluded elementary and product flows with mass and energy cumulative contributions under 1% of the final concentrates composition.

We also excluded components whose production technology was unknown, as well as those with low environmental relevance according is conceptualized on standard ABNT NBR ISO 14044 [7].

Data coverage: regarding temporal coverage primary data were collected for a period of eleven months along 2010/2011 period. The geographic scope includes the cities located in the states of Sao Paulo and Bahia. In the State of São Paulo are developed HD 410 and HD 201 manufacturing, apart of the most of the reagents that constitute them. Besides, in the same place are located distribution centers and storage; and the scenarios of use and final disposal selected to carry forward the study. In Bahia occur the productions of two important reactants: LAB, used in HD410' manufacture; and sodium hydroxide, that is used for both formulations. Finally, the technology coverage covers process routes for each product system, such as these were previously described.

Allocation: during the study it was not necessary to use any allocation criterion.

Impact Assessment categories and models: as mentioned before, to meet to the objective of providing market information there were selected indicators: Greenhouse Gases Emission; Water Consumption; and Ecological Footprint.

For GHG emissions was adopted the method developed by the International Panel on Climate Change (IPCC) in 2007, which express GHG contributions as CO<sub>2</sub> equivalent – CO<sub>2</sub>eq – respectively for different timeframes [10].

Water consumption was determined for the sum of water consumptions that occurred in all of unit process considered in product systems. These values were normalized to the respective reference flows before their accounting.

As described in Frischkenht et. al (2007), the Ecological Footprint's indicator is defined as the biologically productive land and water that population requires to produce the resources it consumes and to absorb part of the waste generated by fossil and nuclear fuel consumption. So to the LCA's context, the ecological footprint of a product is defined as the sum of time integrated direct and indirect land occupation, related to nuclear energy use and to CO<sub>2</sub> emissions, from fossil energy [11]. To the present study, Ecological Footprint was modeled just in terms of land occupation. In this frame, the models output was expressed as square meter-year (m<sup>2</sup>a).

In order to achieve its other strategic goal, RL-H and GP2 decided for a set of rigorous and analytical indicators, provided by CML 2000. This is a method based on 'problem oriented approach', and 'damage approach'. In case several methods are available for obligatory impact categories a baseline indicator is selected, based on the principle of Best Available Practice (BAP). The baseline indicators, recommended to simplified studies, are category indicators at midpoint level (problem oriented approach) [11].

The impact category set used to the study considered: Ozone layer depletion; Human toxicity; Terrestrial ecotoxicity; Photochemical oxidation; Acidification; Global warming (GWP100); Abiotic Depletion; and Eutrophication.

### ***3.2 Life Cycle Inventory general assumptions***

In order to build up the Life Cycle Inventories (LCIs) of HD410 and HD201 some specific assumptions were established. These are indicated below:

According to the exclusion criteria before defined no longer were considered for effect of this modeling: isothiazolinone, and yellow dye (in the product system of HD410); and blue dye, and lemon essence for HD201.

In both cases, it was considered that hydrated ethylic alcohol is produced from sugarcane tillage performed in São Paulo State. All of the environmental loads from this product were collected from primary data.

Sodium hydroxide (NaOH) is also used as reactant to the formulations of HD410 and HD201. In order to express the environmental loads related to this production a technological mix based on ABIQUIM's Yearbook - 2010 [12] was considered. This includes: 55.1% of NaOH's production by mercury cell; 23.5% by diaphragm; and 21.4% by membrane.

LCIs from each of these process routes were customized to the Brazilian condition from databases for homologous processes performed in Europe that were collected in Ecoinvent Platform [13].

Environmental burdens related to processing of Triethanolamine, EDTA and the surfactant (LAB) - that are also common for manufacturers of two cleaners for professional use - were, in the same way, collected from Ecoinvent Platform [13]. As in the case of NaOH, these databases passed through adaptations - especially regarding the Brazilian energy matrix.

Similar methodological approach was carried on to silicone (defoamer), ethoxylate alcohol, and amine oxide to the case of the HD410; and, to surfactant (LESS), and the solvents glycol and isopropanol, with respect to the HD201.

For the cases in which process technology was unknown, environmental burdens associated with such transformations were obtained by approximation. For situation like this, scientific and technical literatures were used for data collection, and the environmental aspects were estimated by stochastic simulation software.

Environmental issues relating to generation and transmission of electric energy were calculated from data supplied by the National Energy Balance (BEN) [14].

Distances and transport's modes were modeled according to information provided by companies responsible for such services. In absence of such data, usual routes of travel, gathered from sources consistent and representative were adopted.

Storage of chemical reagents was modeled from average data consumption and shelf life from data collected for RL-H's storehouse.

As to attend the selected function each product should be diluted in specific level, environmental burdens profile associated to capture, processing and distribution of water were considered for the purpose of this performance analysis.

Considering the biodegradability grade of HD 410 and HD 201, it was assumed as 90%, the removal rates of COD and BOD<sub>5</sub> for the treatment of effluents generated as a result of their use for cleaning the analyzed area [2,15].

For those cases of primary data unavailability and lack of measurement conditions to make it were estimated environmental loads from mass and energy balances using parameter similar process.

Finally, only verifiable input and output flows were effectively modeled.

## 4 Results and Discussion

Comparative analysis of environmental impacts associated with the functional unit 'to keep it clean daily 85m<sup>2</sup> tile floor of an industrial cafeteria in business center' by the application of HD410 and HD201 was performed with aid of SimaPro 7.0 - version 7.2.4 [16]. Following are presented the results for the two approaches that the study proposes.

### *4.1 Comparison of the environmental performance HD410 vs. HD201: Life Cycle Management - downstream approach*

Table 1 provides data for a comparative environmental performance analysis of HD410 and HD201 of Greenhouse Gases Emissions (GHG), Water Consumption, and Ecological Footprint.

**Tab.1: Environmental comparative analysis of HD410 and HD201**

Category	Unit	HD410	HD201
Greenhouse Gases Emission	kg CO <sub>2</sub> eq.	89	113
Water Consumption	L	513	293
Ecological Footprint	m <sup>2</sup> a	0.028	0.067

An analysis of data from Table 1 lets observe that HD201 generates 27.4% more GHG emission than HD410. This difference is related to the use of hydrated ethyl alcohol to formulate HD410. As ethanol is produced from sugarcane, there is a positive contribution from the agricultural process regarding to carbon fixation. Moreover, HD410 imposes higher water consumption than HD201 because of the irrigation procedures performed during sugarcane tillage.

Monteiro & Menegazzo (2005) observe that sugarcane tillage in Sao Paulo State has an average water consumption of 500L/ha [17]. Queiroz, et. al. (2005) reported that sugarcane requires 250 parts of water in order to form a part of dry matter, and that a crop cycle takes 100-200mm of water [18]. Finally, water in both products' formulas is significant: 59% for HD410 and up to 62% for HD201. Regarding Ecological Footprint, HD201 occupies 0.067m<sup>2</sup>a area against 0.028m<sup>2</sup>a used by HD410. Palm tillage represented the most important individual contribution with about 93% of the total area measured for HD 201.



As for the case of HD 410 stands out coconut production (with a contribution of 87% of total) whose oil is used in the production of amine oxidizes. Besides, can be detached a discrete contribution from sugarcane (2.8%).

Indicators such as those selected for this analysis can serve to establish a strategy based on LCM, in terms of environmental communication with the market.

From these results RL-H hopes to influence the decision making process of its consumers as it provides them information on the environmental dimension of sustainability.

#### ***4.2 Comparison of the environmental performance HD410 vs. HD201: Life Cycle Management - upstream approach***

Seeking to meet the second of the strategic objective of RL-H, a comparative environmental performance analysis of HD410 and HD201 - based on midpoint indicator - provided by the impact assessment method from CML baseline 2000 was performed. These results are presented in Table 2.

**Tab. 2: Environmental comparative analysis of HD410 and HD201 performed by CML baseline 2000**

Impact category	Unit	Higindoor 410, at use - Process	Higindoor 201, at use - Process
Abiotic depletion	kg Sb eq	1.16E-03	1.56E-03
Acidification	kg SO <sub>2</sub> eq	4.80E-04	8.01E-04
Eutrophication	kg PO <sub>4</sub> <sup>3-</sup> eq	2.97E-04	4.37E-04
Global warming (GWP100)	kg CO <sub>2</sub> eq	7.32E-02	1.24E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	6.80E-09	9.49E-09
Human toxicity	kg 1,4-DB eq	8.43E-02	4.84E-01
Terrestrial ecotoxicity	kg 1,4-DB eq	5.74E-04	2.66E-02
Photochemical oxidation	kg C <sub>2</sub> H <sub>4</sub>	2.19E-05	1.64E-04

HD201 seems to be more aggressive in terms of impacts to the environment and the human being than HD410. Regarding Abiotic depletion, HD201 added 1.16E-3kg Sb<sub>eq</sub>/RF, a value 34.5% higher than the total generated by the HD410. This was due to crude oil consumption for intermediate chemicals' production. The production of propylene - used by isopropyl alcohol and 1-Buthanol synthesis, contributed 22.9% of this total. Follows it the production of ethylene (11.2%) used

in the EDTA' production. 1-Butanol - used by 2-Butoxyethanol synthesis - also brings impacts, because of its intensive demand for natural gas. For HD410 most important contributions are also related to intermediate raw materials that are petroleum derivate: ethylene (23.6%) also for EDTA' production; benzene (9.7%) used in alkyl benzene sulfonate linear manufacture - an input of LAS - and for NaOH synthesis; and natural gas (5.3%), a heat source for triethanolamine and hydrogen peroxide processing.

The main environmental aspects associated to Acidification, refers to emissions of sulfur oxides ( $\text{SO}_x$ ), nitrogen oxides ( $\text{NO}_x$ ) and ammonia ( $\text{NH}_4^+$ ). Contributed to  $8.01\text{E-}4 \text{ kgSO}_2\text{eq./RF}$  by HD201, the unit processes as: secondary sulfur (18.4%) - later used for SLES synthesis; propylene (5.7%) and ethylene (2.8%). HD410 showed a profile similar to its homologous; of the total Acidification in its product system -  $4.08\text{E-}4 \text{ kgSO}_2\text{eq./RF}$  - the secondary sulfur obtaining adds 14.7%, and ethylene's production, 7.9%. Besides, stand out emissions of  $\text{NO}_x$  and  $\text{NH}_4^+$  in sugarcane tillage (8.5% of total), and  $\text{SO}_x$  in benzene synthesis (5.0%).

Both product systems had in their respective 'use' stages, significant contributions for Eutrophication, a conclusion somehow expected when it comes to cleaning products. For HD201, the remaining COD of the effluent treatment arising from its application corresponded to 42.8% of the total. In HD410 it was noticed a similar behavior, with a contribution of 61.3% of  $2.97\text{E-}4 \text{ kg PO}_4^{3-}\text{eq./RF}$  to 'use' step. Besides, losses of nitrate ( $\text{NO}_3^-$ ), phosphate ( $\text{PO}_4^{3-}$ ) and ammonia ( $\text{NH}_3$ ) in sugarcane tillage, accounted together 3.3%.

HD201 counts a contribution of  $1.24\text{E-}1 \text{ kgCO}_{2\text{eq./RF}}$  for Global Warming. Of this total, 75.1% refers to power needs along its production chain, which are supplied by fossil fuels burning. Finally, It is noteworthy, carbon sequestration in palm fruit tillage in SLES' production chain, of  $0.10 \text{ kgCO}_{2\text{eq.}}$

Exactly 49.7% of GHG emissions from HD410 refer to  $\text{CO}_2$  from fermentation carried on to obtain ethylic alcohol. Besides, natural gas burning in ethylene's synthesis of should be highlighted (17.2%). As observed, carbon sequestration in sugarcane tillage decreases in of  $0.0505 \text{ kgCO}_{2\text{eq./RF}}$ .

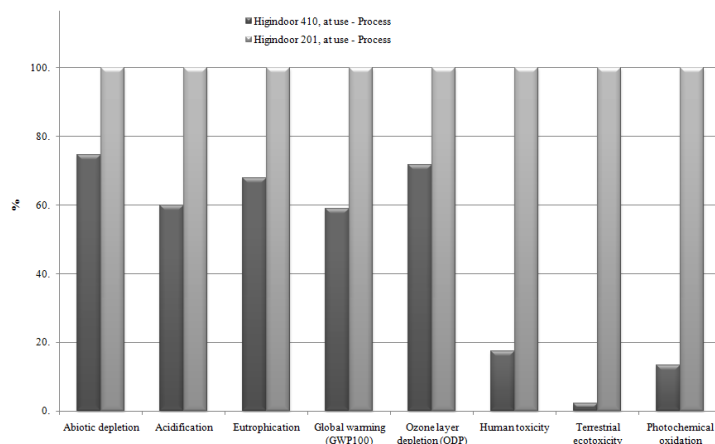
Ethylene oxide's loss is a significant environmental load as Human Toxicity for both products. For HD201, it occurs in 2-Butoxyethanol production and adds 82.4% of the total account. Releases of ethylene oxide during triethanolamine manufacture, contribute with 37% of total in the case of HD410.

Pesticides add the main loads for Terrestrial Ecotoxicity in both cases analyzed. Cypermethrin applied to palm fruit tillage provides 97.7% of the total measured for HD201. Diuron's dosage to control pests in sugarcane, add almost all of the  $9.53\text{E-}5 \text{ kg1-4DBeq./RF}$ , corresponding value of 16.6% of the total impact for the category for HD410.

The main contribution as Photochemical Oxidation, associated to HD201 occurs in palm kernel tillage (20.0%), due to CO<sub>2</sub> and hexane losses. From the total addition generated by HD410, contributions from productions of secondary sulfur (12.9%) and ethylene (9.5%), due to SO<sub>x</sub> emissions; and ethylene oxide obtaining (8.1%) by ethene emissions into air can be highlighted.

Finally, impacts in terms of Depletion of Ozone Layer were considered as supposedly discrete in both cases. A comparison of HD410 and HD201 using the methodological approach of CML baseline 2000 is shown in Figure 1.

**Fig.1: Comparative environmental impact profile for HD410 and HD201 obtained by CML baseline 2000**



Besides Eutrophication, all of the other environmental impacts assigned to HD410 and HD201 were observed along their supplying chains. This reinforces adoption of a systemic management policy based on Life Cycle approach, in which should be included Industrial Ecology, Cleaner Production and Resource Efficiency.

## 5 Conclusões

The partnership project developed between the RL-H, its supplier - for HD410 and HD201, and the GP2, met the expectations defined in both level of analysis. With down stream's approach the company got information to reinforce compromises manifested in its Environmental Policy; and consolidates a proactive image of nature preservation, which can be converted into advantage over the competition.

On the other hand, with approach of upstream executive committee proposed three alternative scenarios: discontinue production of the HD201, and increase HD410's production; develop partnership with HD201' vendor to amend its formulation in order to better its environmental performance; or, develop a new multipurpose cleaner that adds good performance in terms of environmental sustainability to the functional benefits to which it proposes.

## 6 References

- [1] GHG - Greenhouse gases Protocol. *A Corporate Accounting and Reporting Standard*. Janet Ranganathan (Coord.). Washington. 2009. 116p.
- [2] OLEAK - *Process Datasheet*. Internal Document. Cotia. 2010. 7p.
- [3] Smulders, E. (coord.): *Laundry Detergents*. Ullmann's Encyclopaedia of Industrial Chemistry 2002, Wiley-VCH, Weinheim. a08 - pp315.
- [4] Krossing, K, *Surfactants*. Ullmann's Encyclopaedia of Industrial Chemistry, 2005, Wiley-VCH, Weinheim. a25 – pp747.
- [5] Baselt, R., *Disposition of Toxic Drugs and Chemicals*. Man, 8Ed. Biomedical Publications, Foster City, CA, 2008, pp. 208-210
- [6] ABNT – Brazilian Association of Technical Standards. NBR ISO 14040 - Gestão ambiental - *Princípios e estrutura*. 2009. 27 p
- [7] ABNT – Brazilian Association of Technical Standards. NBR 14044 - Gestão ambiental - *Requisitos e orientações*. 2009. 52 p
- [8] ABRALIMP - Brazilian Association of Market Professional Cleaning. Normative no. 59.2010. 12p. - <http://www.abralimp.org.br> (Accessed: 26.02.2011)
- [9] OLEAK - *Training Manual. Cold Floors Treatment*. Internal Document. Cotia. 2008. 76p.
- [10] IPCC – Intergovernmental Panel of Climate Changes. *Fourth Assessment Report of IPCC*. Geneva, 2007. pp 104
- [11] Frischknecht, R. (coord.) *Implementation of Life Cycle Impact Assessment Methods: Data v2.0*. Ecoinvent Report 3, Dübendorf. 2007.
- [12] ABIQUIM – Brazilian Association of Chemical Industries - Statistical Yearbook 2010. 563pg. São Paulo. 2010
- [13] Althaus, H.J. (coord.). *Life Cycle Inventory Chemicals. Data V2.0*. Ecoinvent Report 8. Dübendorf, 2007. pp. 957.
- [14] Ministry of Mines and Energy. *Brazilian Energy Balance*. 2010. 276p.
- [15] Von Sperling, M. *Princípios básicos do tratamento de esgotos*. UFMG. Vol. 2. Belo Horizonte, 2009. 211p
- [16] PRÉ Consultants. *SimaPro, 7.0 – Installation Manual*. Armersfoort, 2009.
- [17] Monteiro, M. V. M.; Menegazzo, O. BVO Terrestre. *In: Tecnologia de Aplicação de Defensivos Agrícolas*, 3, 2005, Cascavel. p.68.
- [18] Queiroz, T. M. De.; Teixeira, M. B.; Coelho, R. D. *Água na medida*. Pelotas, 43, 2005. p. 22-24.