



# **Comparative Life Cycle Assessment of Sanitary Pads and Tampons**

## **GROUP 6**

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## **ABSTRACT**

The work is dedicated to comparative life cycle assessments of two main women hygiene protection facilities – sanitary pads and tampons – using software Sima Pro 7. In the work the life cycle assessment were conducted for sanitary pads (fully), tampons (partly) and for tampons and sanitary pads assemblies (fully).

Goal and scope of the analyses were established and functional units were calculated with respect to time parameters of both pads and tampons. Then, impact categories to consider and assessment method (Eco-Indicator 99) were chosen.

Data on sanitary pads and tampons structure, production process, raw materials processing, transportation, and after-use waste utilization were collected, using both literature investigations and empirical weighting of products.

Four sub-models were created, describing full life cycles and assemblies life cycles for sanitary pads and tampons. Modeling was conducted and results were obtained with the help of Eco-Indicator 99 method.

The results were explained using single score, characterization, normalization, and process contribution tables. The inputs distribution into the main environmental impacts was analyzed with respect to processes inventory and the origin of the numbers obtained.

Human health impacts of toxins in tampons are analyzed in the discussion part.

Conclusions were made concerning the best hygiene facility from environmental point of view, limitations of the investigation, and problems we faced during data collection and assessment.

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# 1. GOAL AND SCOPE

## 1.1. Goal of the assessment

Women protection during their “critical” days is not a problem in a modern world. Great variety of different types of sanitary facilities is provided on the market. Sanitary facilities obviously don’t cause any significant environmental impact during use, but they do during production as well as final waste utilization stages. If somebody would like to make choice among them relying not only on prices and personal preferences but also on environmental friendliness of the product, life cycle assessment should be the main instrument designed to assess product’s environmental impact and compare different types of sanitary facilities referring to this assessment.

We decided to choose for assessment the most popular types of sanitary facilities: sanitary pads and tampons. Women can choose between them according to their “quality of protection” or price, but if both of these criteria are relatively equal – why not to choose facilities that make less negative impact to the environment?

The **goals** of our work are:

- to make life cycle assessments of sanitary pads and tampons;
- to compare environmental impacts of sanitary pads and tampons on basis of made LCA;
- to explain the results and on this basis to give advice to women that want to use more environmentally friendly products;

This is an *attributorial comparative type* of LCA that describes two systems and compares their environmental impacts. The **goal auditory** is all women.

## 1.2. Functional unit

We have chosen for life cycle comparison the following **types of products**:

- sanitary pads: “Libresse invisible, ultra thin, normal cap” – 14-pack (see figure 2);
- tampons: “Ob super” – 16-pack (see figure 3);

We consider these particular patterns of pads and tampons as representative products for two reasons: first, they are very popular among women all over the world and in Sweden in particular; second, data on their production and disposal are quite detailed and comprehensive.

Functional unit has been chosen according the main function of the products and with respect to time parameter – number of product providing *effective protection during 1 year for 1 average woman*.

Given types of tampons are designed for 4-5-hours protection, and given type of pads – for 2-4 hours protection. In average, during 1 day woman uses either 3 tampons or 4 pads (as she doesn’t stand up to change it during the night). An average period lasts 3-5 days each 4 weeks, so it happens 13 times a year. Multiplying 3 and 4 (number of items per a day) on 4 (average number of days), and then on 13, we get numbers 156 and 208 correspondingly (items used during a year). In one package there are 16 tampons or 14 pads. According to this, during 1 year an average woman uses in general 10 packages of tampons or 15 packages of sanitary pads.

Thus, functional unit corresponds to 15 packages of sanitary pads or 10 packages of tampons. It is transferred into weight measurement units below (see tables 1 and 3).

## 1.3. System boundaries

**Boundaries in relation to nature:** The assessment includes all stages of products’ life cycle, from “cradle” to “grave”, that means from raw material extraction through their transportation and production process, to usage stage and wastes utilization.

In the case of tampon the “*cradle*” of life cycle can be defined as the cultivation and production of cotton. For sanitary pads the main components are cellulose and plastics such as polyethylene and polypropylene. These ingredients are obtained from the natural system after conversion of raw materials such as wood and crude oil.

The “*grave*” of the sanitary products life cycle is the burning of the used products and empty packaging material at the incineration plant or lanfilling.

**Geographical boundaries:** Considered production processes take place in many different countries (e.g. Sweden, New Zealand, US, Slovakia, Netherlands, France, Australia). Raw materials and products are transported to long distances all over the world. The products are used in many countries all over the world, including Argentina, Bolivia, Czech Republic, Denmark, Ecuador, Finland, Netherlands, Italy, Mexico, Peru, and Russia etc. Transportation data taken for analysis refer to average transportation data of SCA including transportation of both raw materials and final product to all consumers all over the world. It refers also to all kinds of products, which is not very good for our particular investigation, but higher level of detail is inaccessible.

**Time boundaries:** We tried to use the latest data for assessment; especially concerning production process parameters and material flows. Most of the data used relate to 2005 (in particular, SCA environmental report and information from “Libresse” site).

**Cut-off:**

For tampons we include in LCA only impacts of assembly and waste utilization due to lack of data on production and transportation processes.

## 1.4. Assumptions and limitations

We have set the range of **limitations** and made several **assumptions** concerning the project:

- we investigate only two specific types of products, despite their great variety on the market;
- we assume that technological processes of sanitary facilities production, the raw materials used and emissions and wastes generated do not differ significantly between the various producers;

## 1.5. Impact categories and impact assessment method

Life cycle impact assessment is defined as the phase in the LCA aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system [1]. According to the objectives of our project we have focused on three main categories that cover all relevant environmental impacts.

• **Human Health** – Respiratory diseases, cancers, infections, disabilities are the most important damages to Human Health caused by emissions from product system. In the concern for women’s health as consumers of either sanitary pads or tampons our aim is to assess the effect of chemicals used on the production stage (for example chlorine bleaching of the cotton). In the wider perspective the goal of our work is to describe how negative effects of climate change or ozone depletion caused by emissions from all product life cycle affect on the human health and his well-being;

• **Ecosystem Quality** – this area consist of Ecotoxicity as a percentage of all species living under toxic stress, Acidification and Eutrophication as a result of biochemical damages (NO<sub>x</sub>, SO<sub>x</sub> and NH<sub>3</sub> deposition), and Land Use this refers to the changes in species number and biodiversity occurring on occupied or converted land. In the paper we would like to reveal to what extend the whole life cycle of our products disturb the ecosystem quality;

• **Resources** – in this category the decrease in resources concentrations due to extraction is measured. Not only energy resources (coal, gas, oil), or raw materials (wood, metals) are taken into consideration, but also an environmental resources such as air, water and soil are covered by this category [2];

Below is the list of all environmental impacts we consider the most relevant to our subject:

- Climate Change
- Ozone Layer Depletion
- Eco-toxicity
- Acidification and Eutrophication
- Land Use
- Use of Fossil Fuels and Minerals

After defining the environmental aspects and acquainting our self with all impacts assessment methods that Sima Pro offers we have chosen *Eco-indicator’99* (I – individualist version as a weighting set of Eco-indicator) V2.1/ Europe EI 99, as the method that fulfils all our requirements. The Eco-indicator 99 scores are based on an impact assessment methodology that transforms the data of the inventory table into damage scores which can be aggregated, depending on the needs and the choice of the user, to damage scores per each of 3 comprehensive damage categories, or even to one single score [2].

## 2. LIFE CYCLE INVENTORY ANALYSIS

### 2.1. Process flowcharts

Process flowcharts and pictures of the sanitary pads and tampons are shown at figures 2 and 3 correspondingly.

### 2.2. Data collection and interpretation

**Data for analysis are obtained** from the following sources:

- empirical weighting of compounds using the laboratory balance with the error of 0.0001 gram;
- environmental report 2005 and other environmental data from the web-site of SCA [3] — famous producer of women hygiene products. Total production of SCA pulp and paper products constitutes 9893 kt, 407 kt of which ( $\approx 4\%$ ) belongs to personal care products. The data available were reported per production facility, some of which produce different other products except of pads. We have chosen 2 mills included in the environmental report 2005 where pads “Libresse” are produced: *Gemerska (Slovakia)* and *Hoogezand (Netherlands)*. Data used for LCA are average between these two mills data for year 2005.

#### 2.2.1. Sanitary pads life cycle data

The early disposable sanitary pads comprised wadding made from cellulose as the absorbent core with a plastic backing and a synthetic fabric sheeting material as the surface closest to the skin. Since then, continuous product innovations took place including the use of super-absorbent polymers. They are now much thinner and much more absorbent as well as being more comfortable to wear and easier to use. A wide range of products is now available, different sizes to suit varying body shapes and anatomies and different levels of absorbency.

Our investigated sanitary pad is from new generation of sanitary towels and consists of 4 main parts (excluding the individual package and the packaging of the whole box) and they are:

1. Top layer;
2. Pad filling (fluffed cellulose);
3. Bottom layer;
4. Paper sheets.

#### Top layer

The external layer of sanitary towel is very important because it has direct contact with the skin; that is why it is essential that it is soft and dry. It is made from a very thin non-woven fabric and transfers blood quickly to the layers underneath (see figure 1).

**Figure 1: “Libresse” pads top layer [4]**



It allows instant transfer of the blood from the contact point on the top surface, through to the acquisition layer immediately below and provides a contact layer to protect the skin from irritation. The top-sheet is in intimate contact with the skin, so it should be very soft to ensure that there is no skin abrasion. It is also the first layer to have contact with the blood flow and needs therefore to be instantly wet-able and have high fluid permeability. Some manufacturers apply a lotion on to the top-sheet to provide additional skin care benefits and antyodour properties. There is also often special perforation used which facilitates better liquid's soaking [5].

#### Pad filling

The absorbent core is the blood storage layer and is the key component in modern pads. It receives the liquid that has been transported through the top-sheet, distributed by the distribution layer and transferred to be locked within the core structure. It has to absorb the blood as fast as it is received and has to allow distribution of the liquid through the structure so that the whole core is utilized.

Figure 2: “Libresse” sanitary pads and LCA flowchart



(1 functional unit = 1.428 kg)

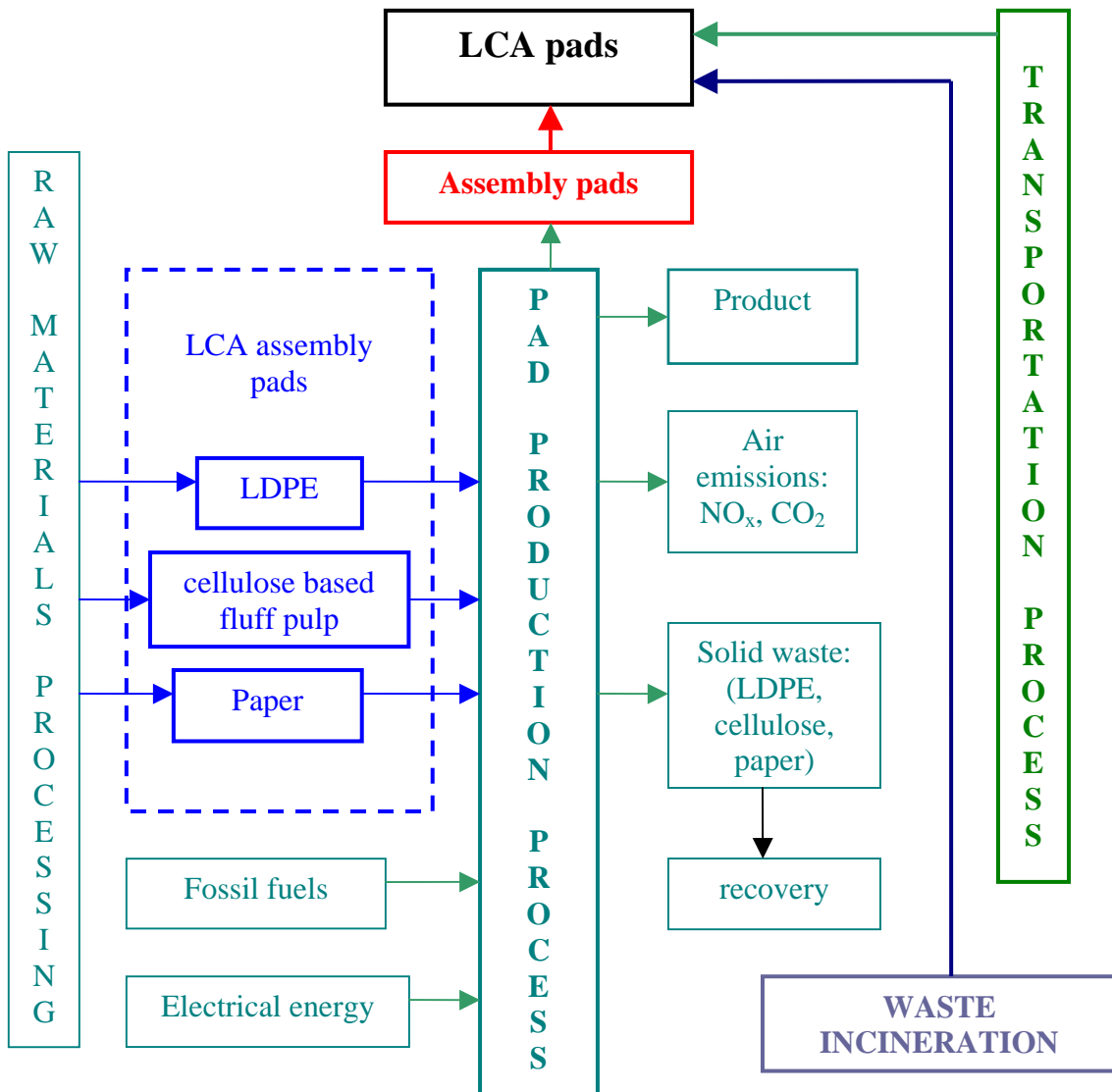
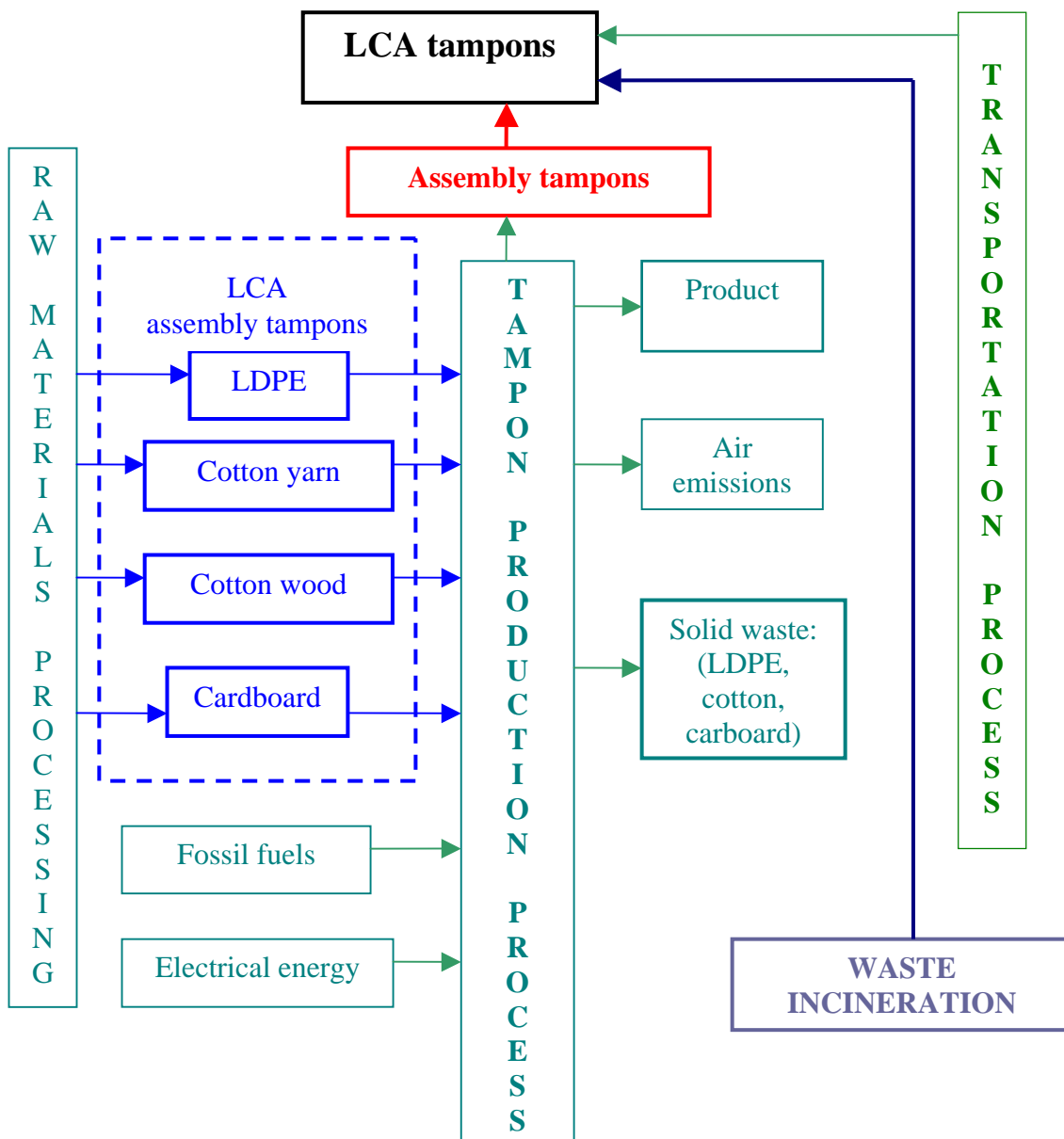


Figure 3: “Ob” tampons and LCA flowchart



(1 functional unit = 0.5835 kg)



The filling part of considered Libresse sanitary pads consists from super adsorbing layer which is called “efficapt” [4]. It is produced from pressed cellulose. “Efficapt” has very good adsorbing characteristics; it also distributes the moisture over the all area of adsorbing material (see Figure 4).

**Figure 4: “Libresse” pads filling: “efficapt” layer [4]**



In our case we assume that the top layer and the pad filling is the one constituent part as soon as they are produced from the same material and they are connected together in such a way that it is difficult to separate them.

**The bottom layer**

It is typically made of ‘breathable’ polyethylene (PE) film or a non-woven and film composite which prevents wetness transfer out of the sanitary napkin.

**Paper sheets**

Paper sheets are made from silicone paper and the main their function is to protect the glue underneath the bottom layer. They are moved off directly before the pad use, and the pad is glued to underwear.

**Sanitary pads production process** in general includes following main sections [6]:

1. pulp;
2. grinding;
3. mat formation;
4. tissue spread (up layer, lower layer);
5. mat section;
6. wrap P.E. Film;
7. hot-melt seal embossing;
8. applying hot melt adhesive;
9. release belt;
10. finished products section;
11. finished products arranged in parallel.

**Raw materials**

All compounds of sanitary pads taken for LCA are listed in the table (see table 1). These data are obtained by empirical weighting of sanitary pads and relating data to 1 functional unit.

**Table 1: Compounds (sub-assemblies) of sanitary pads**

| Part  | Material                   | Weight per 1 package, gram | %      | Weight per 1 funct. unit, kg |
|---|----------------------------|----------------------------|--------|------------------------------|
| Individual package                          | LDPE                       | 11.48                      | 34.790 | 0.4968                       |
| Packaging                                   | LDPE                       | 2.6                        |        |                              |
| Bottom layer                                | LDPE                       | 19.04                      |        |                              |
| Pad filling                                 | cellulose based fluff pulp | 60.4                       | 63.445 | 0.9060                       |
| Paper sheets                                | (silicone) paper           | 1.68                       | 1.765  | 0.0252                       |
| TOTAL (14-package sanitary pads “Libresse”) |                            | 95.2                       | 100    | 1.4280                       |

Pads are produced mostly from fluffed pulp. Synthetic materials are used to enhance quality and functionality, as well as in special high-protection packaging. According to SCA data, 104 kt of products correspond to 17.229 kt of waste. We can calculate that 1 functional unit of pads corresponds to 0.2365674 kg of waste, that means that total raw materials consumption for 1 functional unit is 1.6645674 kg, which includes all pad components. As we know weight of components in 1 functional unit, we can (assuming that waste outcome percentage from different types of raw materials is approximately the same) calculate all raw materials consumption per 1 functional unit of pads (see table 2).

## Transport

The raw materials that are transported to SCA's production plants each year are transported over relatively short distances. The finished products that are delivered to SCA's customer are often shipped over longer distances. The major portion of SCA's transportation is procured from external suppliers.

Most emissions from transportation constitute NO<sub>x</sub>, SO<sub>2</sub> and CO<sub>2</sub>. SCA transport of raw materials and products corresponds to 12 329 TJ fuel and 61 GWh electricity.

SCA transport use corresponds to 29 billion tonne kilometers, which corresponds to 4.18599 tkm per functional unit. Distribution of SCA transport work: ship – 69 %, lorry – 25.2 %, rail – 5.8 %. Thus, transport distribution for functional unit will be the following: ship – 2.8883331 tkm, lorry – 1.05486948 tkm, rail – 0.24278742 tkm.

### Production: energy consumption

Energy for production process comes from national grid and fossil fuels coal, fuel oil and natural gas supplied to the site. Internal hydro-power, co-generation, bio-fuels (renewable energy from process residues) or electric boilers are not used. Energy consumption constitutes: 1.4005 kWhe of electricity and 1.6065 MJfuel of fossil fuel per functional unit.

### Production: air emissions

Air emissions include NO<sub>x</sub> and CO<sub>2</sub> fossil (carbon dioxide derived from combustion of fossil fuels). Per functional unit amount of emissions constitutes correspondingly 0.00016065 kg and 0.10298077 kg. SO<sub>2</sub>, dust and CO<sub>2</sub> biogenic (carbon dioxide derived from combustion of bio-fuel) are not generated.

### Production: water emissions

There is effluent water (water discharged to the watercourse after treatment) – 0.01537846 m<sup>3</sup> per functional unit. COD, BOD, suspended solids, AOX, phosphorus and nitrogen are not generated.

### Production: solid wastes

There are solid wastes generated: 0.2365674 kg per functional unit, all of which are recovered (can be used as raw materials in other industries). There are no hazardous wastes. The amount of different types of waste generated is represented in the table 2.

**Table 2: Raw material consumption and wastes generated during sanitary pads production (kg per 1 functional unit)**

| Materials                | Wastes    | Raw material consumption |
|--------------------------|-----------|--------------------------|
| LDPE                     | 0.0823018 | 0.5791030                |
| Fluffed pulp + cellulose | 0.1518552 | 1.0560848                |
| Silicone paper           | 0.0024104 | 0.0293796                |
| TOTAL                    | 0.2365674 | 1.6645674                |

### Waste utilization after use

Although pads disposal presents no public health or environmental safety risk, disposal in landfills is the least desirable disposal alternative. The best disposal option is *incineration* that range from bulk incineration of municipal solid waste with energy recovery to selective incineration [3]. Used cellulose products function as secondary fuel and can replace fossil fuels such as oil, gas or coal. Use of wood-based fuels also avoids adding carbon to the biosphere.

## 2.2.2. Tampons life cycle data

Modern tampons are mainly composed (over 90% of the tampon) of cellulose absorbent material, either rayon or cotton or a mixture of these fibres [7]. In most instances, the absorbent-core is covered by a thin, smooth layer of non-woven or perforated film helping to reduce loss of fibres and making the tampon easy to insert and remove. The withdrawal cord, or string, that is necessary to remove the tampon is usually made of cotton or other fibres. The tampon is individually wrapped with a paper wrapper or a thin film (e.g. polymeric plastic material or cellophane) before being packed into cartons. If the tampon has an applicator it can be made of either coated paper or polymers or a combination of both [8].

As we assume that taken for LCA “Ob” tampons mostly consist from cotton wool, some facts are represented concerning **cotton wool processing** [9]:

#### Crop production

Cotton minimizes ground water contamination, adapts to poor soils and is an efficient user of fertilizer. Its growing season last approximately 150 to 180 days. Land preparation actually starts in the fall, shortly after harvest. The soil is cleared and precision planters place cottonseed in the soil at a uniform depth and interval. Some plants are improved by modern biotechnology, which causes the plant to be resistant to certain damaging worms.

Young cotton seedlings emerge from the soil within a week or two after planting, depending on temperature and moisture conditions. They ripen and enlarge into a pod called a cotton boll. Bolls open 50 to 70 days after bloom, letting air in to dry the white, clean fiber and fluff it for harvest.

Cotton is almost entirely machine harvested. Then it is formed into modules, covered with water resistant tarps and stored until it can be ginned.

#### Ginning and cleaning

From the field, seed cotton moves to nearby gins for separation of lint and seed. Cotton is transported to the production plant where it is cleaned. First the cotton gets into the feeder which fluffs it before sending to cleaning. Vacuum pipes, water and are used to remove the foreign matter.

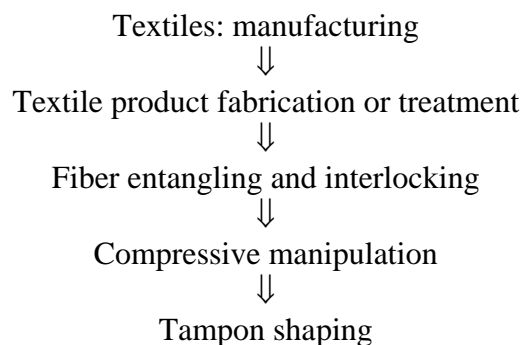
#### Classing

After the cotton is cleaned samples are classified according to fiber strength, sample length, length uniformity, grade color, non-fiber content and fineness.

Cotton of a given variety produces fibers of approximately the same length. Other quality factors also are important. The fiber’s fineness is important for determining the type of yarns that can be made from the fiber—the finer the cotton fibers, the finer the yarns. Color or brightness of the fibers also is important. Cotton that is very white generally is of higher value than cottons whose color may have yellowed. The fiber’s strength also is an important measurement that ultimately influences the fabrics made from these fibers.

A tampon for feminine hygiene comprising a non-woven cover having at least one, outwardly directed, smooth surface and substantially enclosing a liquid absorbing core wherein the non-woven cover comprises at least partly thermoplastic, heat-sealable fibres and pressed to the final shape of the tampon. Before the tampon blank is covered with the non-woven covering web, said web was subject to the use of heat and pressure during the manufacturing of the tampon as to smooth out at least the outer surface of the non-woven covering web, whilst maintaining the structure of the non-woven covering web and the absorbency of the tampon. Thereby, it is achieved that the tampon can also be more easily and more comfortably introduced into and withdrawn from a body cavity before and after the days of stronger menstruation or at the occurrence of only less vaginal exudation as garment protection [7].

**Production Process** in general includes following main stages:



Today there are two main **technologies of shaping tampons** [10]:

- The coiled tampon type starts with a rectangular fibre pad around which a withdrawal cord is looped. The fibre pad is then asymmetrically folded and rolled and then compressed to a cylindrical shape. A number of longitudinal or helical grooves are formed by the compressing

operation. This type of tampon expands radially (like considered “Ob” tampons). Most digital tampons are coiled tampons.

- The second type (typically used for applicator tampons) starts from a rectangular fibre pad. A withdrawal cord is sewn across the length of the tampon fibre pad which is then compressed to a cylindrical shape. Alternatively the withdrawal cord can be attached after the compression by pierce and loop attachment of the cord at the bottom section of the tampon. The tampon expands widthways and lengthwise (like “Tampax” tampons).

### Raw materials and solid waste

All compounds of tampons taken for LCA are listed in the table (see table 3). These data are obtained by empirical weighting of tampons and relating data to 1 functional unit.

**Table 3: Compounds (sub-assemblies) of tampons**

| Part                            | Material    | Weight per 1 package, gram | %      | Weight per 1 funct. unit, kg |
|---------------------------------|-------------|----------------------------|--------|------------------------------|
| Basis                           | cotton wool | 44.32                      | 75.955 | 0.4432                       |
| String                          | cotton yarn | 1.76                       | 3.016  | 0.0176                       |
| Individual package              | LDPE        | 1.44                       | 2.29   | 0.0229                       |
| Packaging                       | LDPE        | 0.85                       |        |                              |
|                                 | cardboard   | 9.98                       | 17.104 | 0.0998                       |
| TOTAL (16-package tampons “Ob”) |             | 58.35                      | 100    | 0.5835                       |

The quantity of waste generated during the manufacture and packaging of tampons must not exceed 10% w/w of the end product [11]. This means that maximum waste amount for tampon production is 0.05835 kg for functional unit, and maximum raw material consumption – 0.64185 kg for functional unit. The amount of different types of raw materials consumed and waste generated is represented in the table 4.

**Table 4: Raw material consumption and wastes generated during tampons production (kg per 1 functional unit)**

| Materials   | Wastes  | Raw material consumption |
|-------------|---------|--------------------------|
| cotton wool | 0.04432 | 0.48752                  |
| cotton yarn | 0.00176 | 0.01936                  |
| LDPE        | 0.00229 | 0.02519                  |
| cardboard   | 0.00998 | 0.10978                  |
| TOTAL       | 0.05835 | 0.64185                  |

### Waste utilization after use

The common waste utilization approach in relation to tampons is incineration.

## 2.3. Modeling

Our first intention to create two comprehensive models unfortunately faced the problem of data lack on tampon production, especially quantitative data. That is why when modeling life cycle for tampons we could include only raw materials consumption, waste generation during tampons production and waste treatment after tampons use. The only comparable aspects can be impacts from pads and tampons assemblies, that is, from extraction and processing of raw materials constituting assemblies.

We had made four sub-models for further analysis:

1. LCA assembly pads (only raw materials impacts for pads);
2. LCA assembly tampons (only raw materials impacts for tampons);
3. LCA pads (the whole pads life cycle);
4. LCA tampons (tampons life cycle, not completed).

All input data arrays for modeling are shown in tables 5 and 6. We have chosen the most appropriate materials available in Sima Pro databases.

**Table 5: Input data for sub-models “LCA assembly pads”, “LCA assembly tampons”**

| Type of data                       | Data from Sima Pro        |  |               | Value  | Unit |
|------------------------------------|---------------------------|--|---------------|--------|------|
|                                    | Name of data              | Process                                | Database      |        |      |
| <b>Sanitary pads</b>               |                           |  |               |        |      |
| Material: LDPE                     | LDPE A                    | Material/ plastics/ thermoplasts       | Industry data | 0.4968 | kg   |
| Material: fluffed pulp + cellulose | Cellulose sulphate BBC    | Material/ paper + board/ pulp          | BUWAL 250     | 0.9060 | kg   |
| Material: silicone paper           | Paper woody C B250        | Material/ paper + board/ graphic paper | BUWAL 250     | 0.0252 | kg   |
| <b>Tampons</b>                     |                           |  |               |        |      |
| Material: cotton wool              | Cotton fibres I           | Material/ textiles                     | IDEMAT 2001   | 0.4432 | kg   |
| Material: cotton yarn              | Cotton fabric I           | Material/ textiles                     | IDEMAT 2001   | 0.0176 | kg   |
| Material: LDPE                     | LDPE A                    | Material/ plastics/ thermoplasts       | Industry data | 0.0229 | kg   |
| Material: cardboard                | Carboard cellulose S B250 | Material/ paper + board/ board         | BUWAL 250     | 0.0998 | kg   |

**Table 6: Input data for sub-models “LCA pads”, “LCA tampons”**

| Type of data  | Data from Sima Pro                           |  |                   | Value     | Unit |
|---|--|--|-------------------|-----------|------|
|   | Name of data                                 | Process                                | Database          |           |      |
| <b>Sanitary pads</b>                                |  |  |                   |           |      |
| Raw materials consumption: LDPE                     | LDPE A                                       | Material/ plastics/ thermoplasts       | Industry data     | 0.5791030 | kg   |
| Raw materials consumption: fluffed pulp + cellulose | Cellulose sulphate BBC                       | Material/ paper + board/ pulp          | BUWAL 250         | 1.0560848 | kg   |
| Raw materials consumption: silicone paper           | Paper woody C B250                           | Material/ paper + board/ graphic paper | BUWAL 250         | 0.0293796 | kg   |
| Waste generation: LDPE                              | Polyethylene waste                           | Material/ others/ pads                 | Final waste flows | 0.0823018 | kg   |
| Waste generation: fluffed pulp + cellulose          | Packaging waste, paper and board             | Material/ others/ pads                 | Final waste flows | 0.1518552 | kg   |
| Waste generation:: silicone paper                   |  |  |                   | 0.0024104 | kg   |
| Industrial waste utilization                        | Recycling paper/RER S, Recycling PE/RER S    | Waste treatment/ recycling             | Ecoinvent system  | Recovery  |      |
| Energy consumption: electricity                     | Electricity, hydropower, at power plant SI/S | Energy/ hydro                          | Ecoinvent system  | 1.4005    | kWh  |
| Energy consumption: fossil fuel                     | Energy coal I                                | Energy/ electricity by fuel/ coal      | IDEMAT 2001       | 1.6065    | MJ   |

| Type of data                           | Data from Sima Pro          |                                  |                     | Value        | Unit |
|--|-----------------------------|----------------------------------|---------------------|--------------|------|
|  | Name of data                | Process                          | Database            |              |      |
| Emissions: NO <sub>x</sub>             | Nitrogen oxides             | Material/ others/ pads           | Airborne emission   | 0.00016065   | kg   |
| Emissions: CO <sub>2</sub>             | Carbon dioxide, fossil      | Material/ others/ pads           | Airborne emission   | 0.10298077   | kg   |
| Effluent water                         | Water                       | Material/ others/ pads           | Waterborne emission | 0.01537846   | kg   |
| Transport: ship                        | Sea ship B250               | Transport/ water                 | BUWAL 250           | 2.88833310   | tkm  |
| Transport: rail                        | Rail transport ETH S        | Transport/ rail                  | ETH-ESU 96          | 0,24278742   | tkm  |
| Transport: lorry                       | Transport, lorry 16t/CH S   | Transport/ road                  | Ecoinvent system    | 1.05486948   | tkm  |
| Waste utilization after use            | Incineration 2000 B250 (98) | Waste scenario/ incineration     | BUWAL 250           | Incineration |      |
| <b>Tampons</b>                         |                             |                                  |                     |              |      |
| Raw materials consumption: cotton wool | Cotton fibres I             | Material/ textiles               | IDEMAT 2001         | 0.48752      | kg   |
| Raw materials consumption: cotton yarn | Cotton fabric I             | Material/ textiles               | IDEMAT 2001         | 0.01936      | kg   |
| Raw materials consumption: LDPE        | LDPE A                      | Material/ plastics/ thermoplasts | Industry data       | 0.02519      | kg   |
| Raw materials consumption: cardboard   | Carboard cellulose S B250   | Material/ paper + board/ board   | BUWAL 250           | 0.10978      | kg   |
| Waste generation: cotton wool          | Production waste            | Material/ others/ tampons        | Final waste flows   | 0.04432      | kg   |
| Waste generation: cotton yarn          |                             |                                  |                     | 0.00176      | kg   |
| Waste generation: LDPE                 | Polyethylene waste          | Material/ others/ tampons        | Final waste flows   | 0.00229      | kg   |
| Waste generation: cardboard            | Carboard waste              | Material/ others/ tampons        | Final waste flows   | 0.00998      | kg   |
| Waste utilization after use            | Incineration 2000 B250 (98) | Waste scenario/ incineration     | BUWAL 250           | Incineration |      |

### 3. LIFE CYCLE INTERPRETATION

As mentioned in the beginning of the report, three impact categories have been taken into consideration during assessments. Below results, interpretation and observation of our work are presented with the references to these three impacts categories (Human Health, Ecosystem Quality and Resources). Also an effort has been made to combine the environmental impacts with the particular emissions, actions and problems resulting from production, usage and waste handling stage.

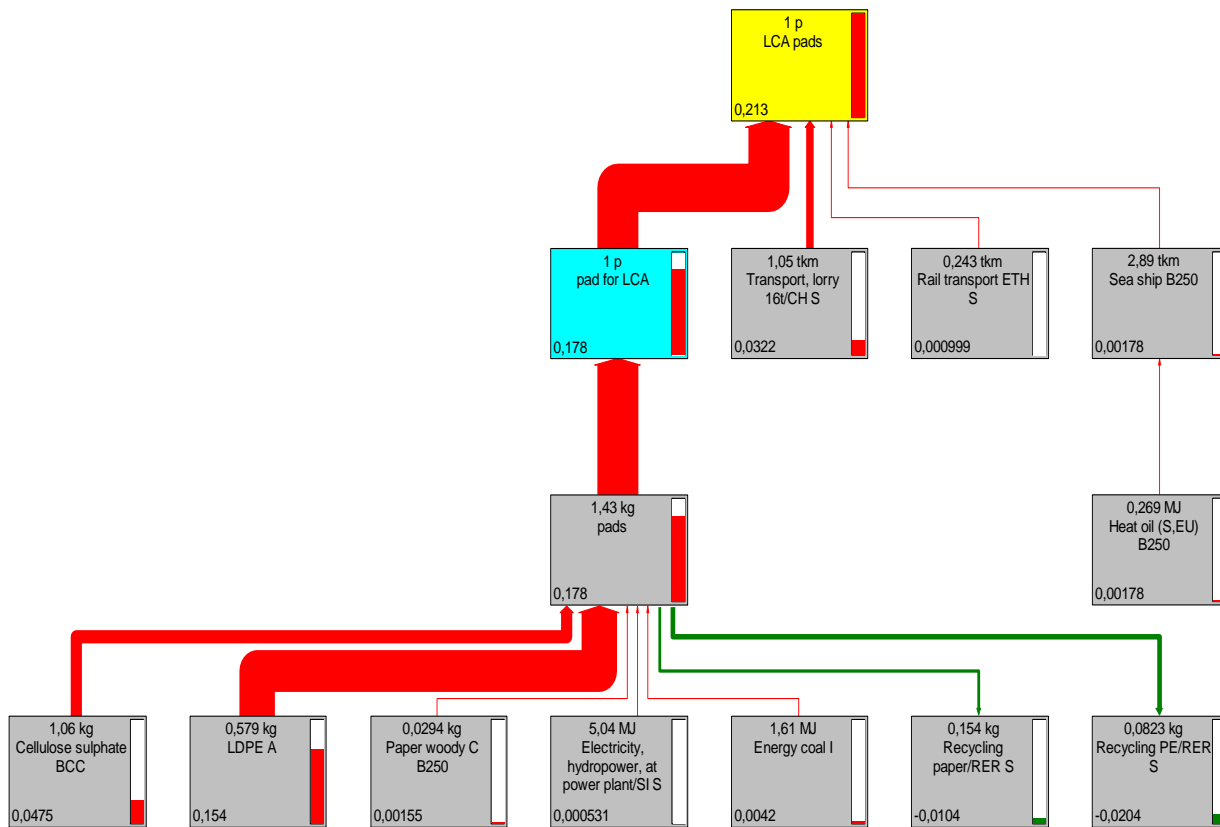
The results of the modeling for further interpretation and analysis can be divided (according to sub-models) into three sub-parts:

- pads life cycle;
- comparison of impacts from pads and tampons material assemblies;
- analysis of tampons life cycle compared to pads life cycle.

#### 3.1. Sanitary pads LCA

Flowchart for pads LCA is represented on the figure 5.

Figure 5: Flowchart pads LCA, single score



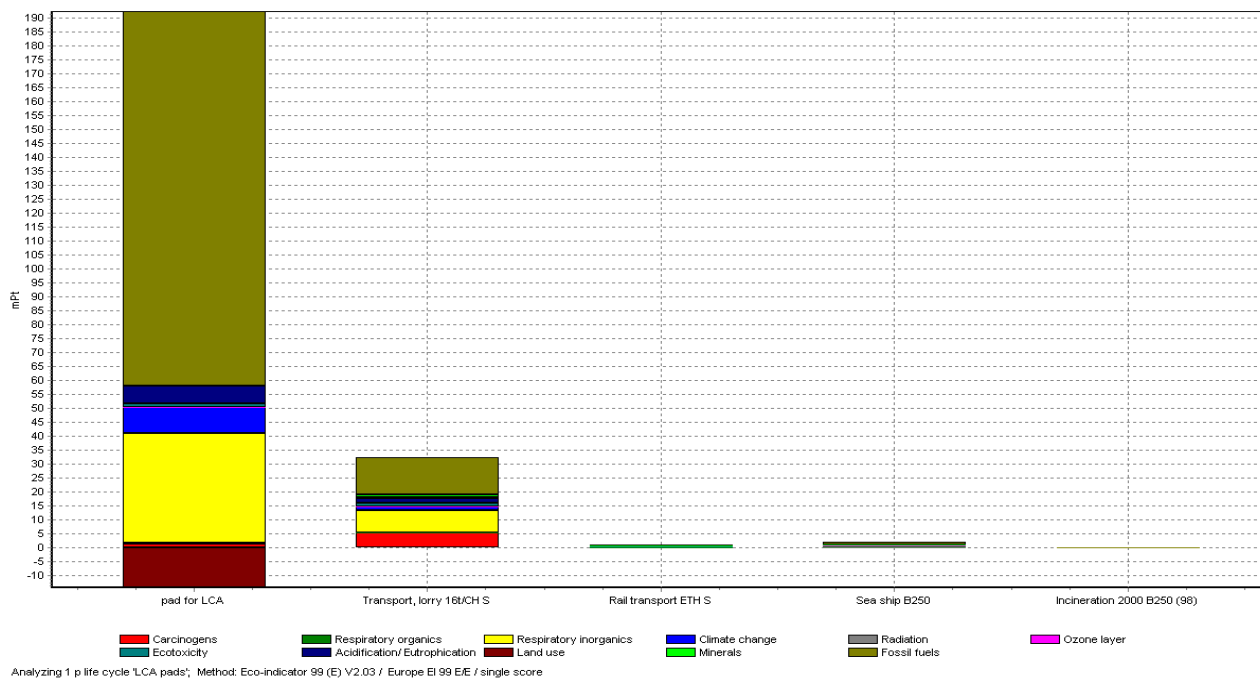
In this flowchart the arrows represent the single score. As it can be seen, the major input into total impact belongs to raw materials processing part, in particular, LDPE and cellulose production. It can be explained if take into consideration that LDPE production, as each plastic production, requires much energy, especially when produced from virgin material. And this high-energy-consuming material constitutes one third of total pad weight.

Although ship transportation values exceed quantitatively lorry transportation values, it obviously makes less negative impacts on environment as it releases less greenhouse gases and thus less pollutes atmosphere. Transportation by lorry is the second greatest contributor into summary impact.

From impact assessment single score (see figure 6) we can see that pads' raw materials processing and pads transportation results mostly in fossil fuel consumption, release of respiratory inorganic, carcinogens, and also in climate change. Recovery of cellulose makes input into "negative" impacts on land use as it decreases the amount of land used for forestry when using cellulose as a virgin material. But it is mostly explained by the fact that chosen material "cellulose sulphate BBC" (see tables 5 and 6),

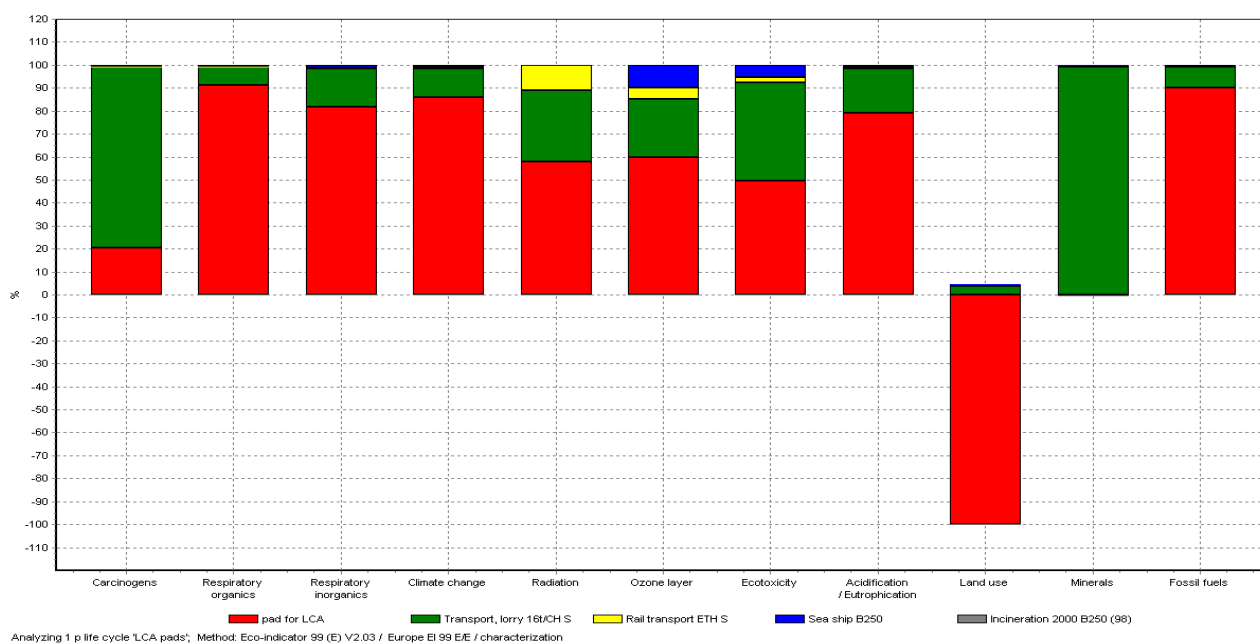
considered as the best alternative when making a choice concerning appropriate materials from Sima Pro databases, doesn't actually include land use impact as a real forestry does (because it implies artificial wood). Inconsistency between databases for recovered cellulose "recycling paper/RER S" (that includes land use) and "virgin" "cellulose sulphate BBC" (that doesn't) creates such kind of "negative" impact that is not possible in reality in this case.

**Figure 6: Pads LCA – impact assessment, single score**



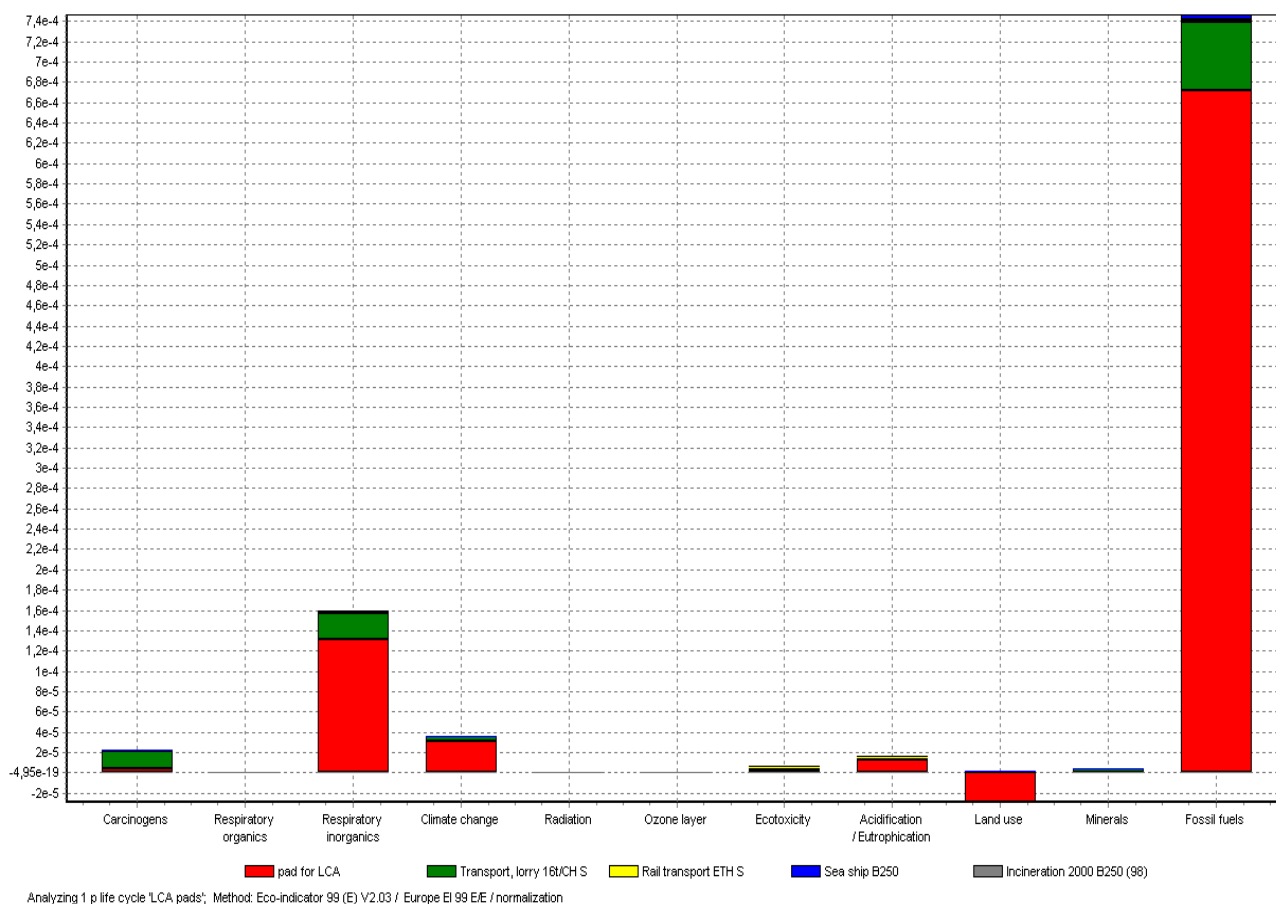
Looking at characterization picture (figure 7), we can learn that in all considered impacts pads' raw material processing does the largest input except of carcinogenic impact and minerals extraction, where the largest input comes from transportation by lorry. Transport results mostly in ecotoxicity and ozone layer depletion.

**Figure 7: Pads LCA – impact assessment, characterization**



In a normalization stage (see figure 8) we got the picture indicating quantitative impacts numbers in comparison, demonstrating also inputs from different processes within pads' life cycle. This diagram summarizes two previous figures, more clearly showing quantitative values of impacts and processes contribution at the same time.

**Figure 8: Pads LCA -- impact assessment, normalization**



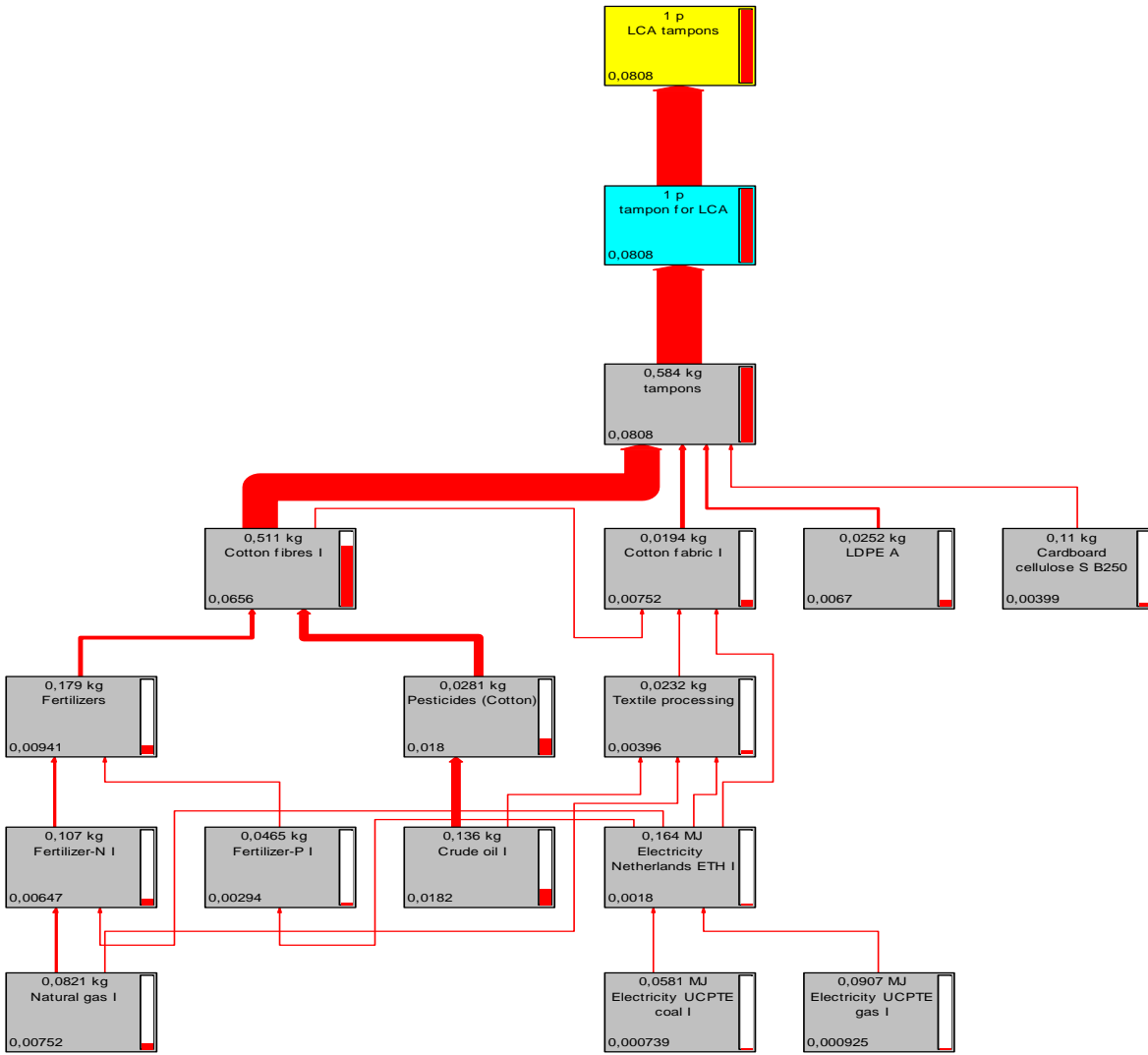
### 3.2. Comparison of impacts from pads and tampons assemblies

The most reliable data for analysis refer to material assemblies of sanitary pads and tampons. For making conclusions concerning the question “what is best to choose: pads or tampons” we are concentrating on different impacts from assemblies-constituting raw materials extraction and processing, their descriptions and explanations. It can't be the only source of “write” answer as comprehensive basis for answer is full life cycles analysis, but in many cases it is the assembly that adds most to the total impact on environment. It is so for sanitary pads (see figure 5), and assuming that for tampons it is also true this comparison is quite righteous and practically valuable.

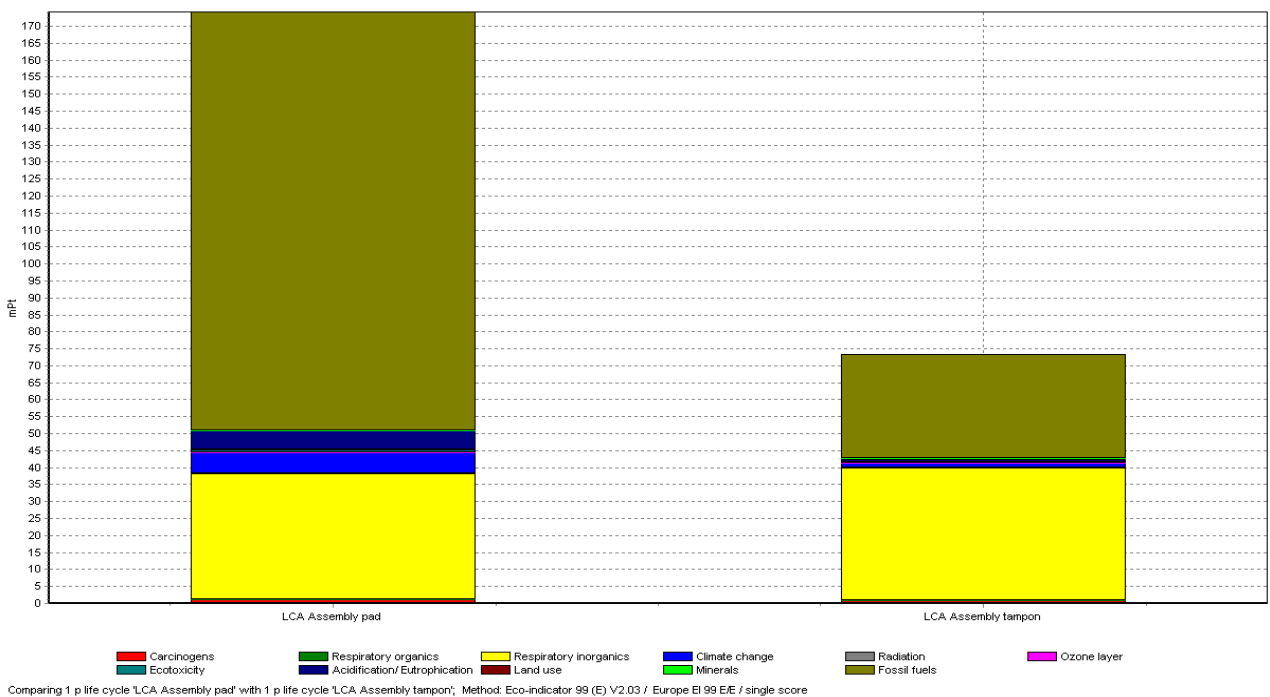
First, we would concentrate on flowchart for tampons LCA which is represented on the figure 9. Cotton fibre is obviously the most significant assembly compound which contributes at about 80% of total environmental impact. It is not surprising: cotton wool takes 76% of tampons weight, and its processing is highly resource-demanding. Cultivating cotton requires large amounts of water, pesticides and fertilizing.

If to look at impact assessments in comparison (figure 10) we can see that absolute numbers for pads assembly are more than twice as high as for tampons assembly. For pads fossil fuel consumption impact exceeds respiratory inorganics, whereas for tampons respiratory inorganics are on the first place, and fossil fuels – on the second. This difference can be explained if remember that LDPE – the most significant pad part – is produced from oil (one of the most valuable fossil fuels), and cotton is an agricultural product, which, when cultivated, causes pesticides and fertilisers releases.

**Figure 9: Flowchart tampons LCA, single score**

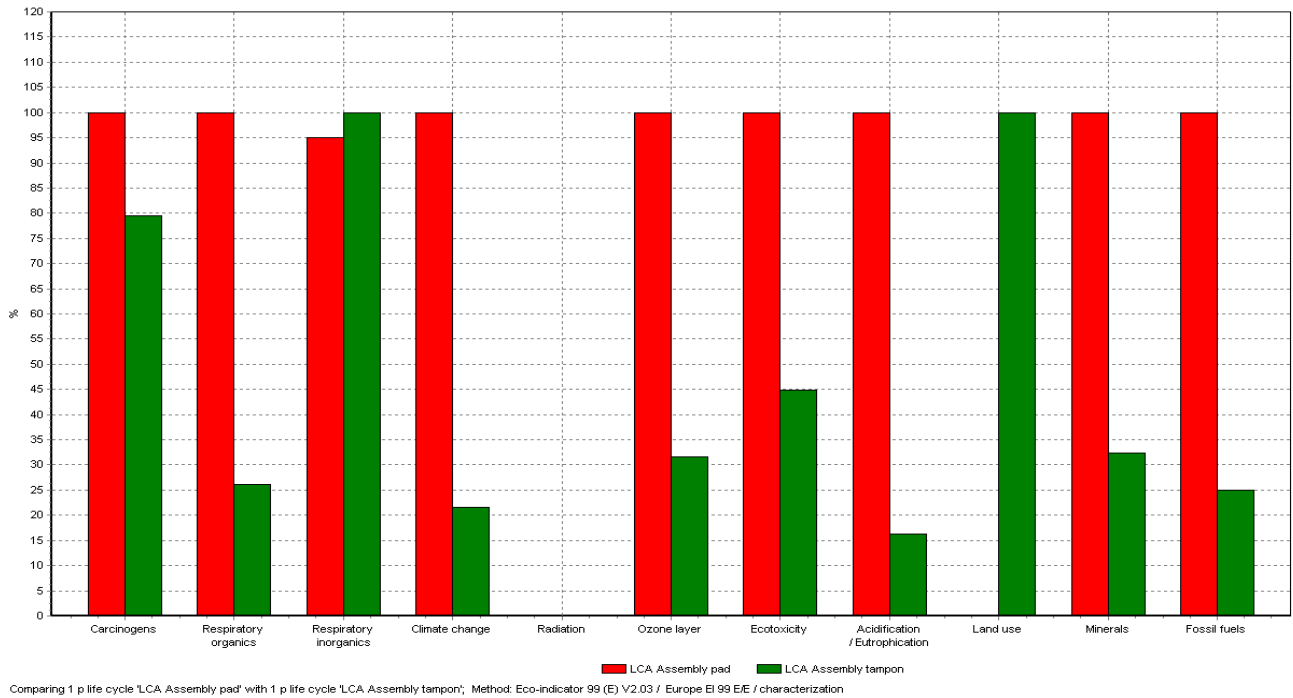


**Figure 10: Pads vs. tampons comparative assemblies LCA – impact assessment, single score**



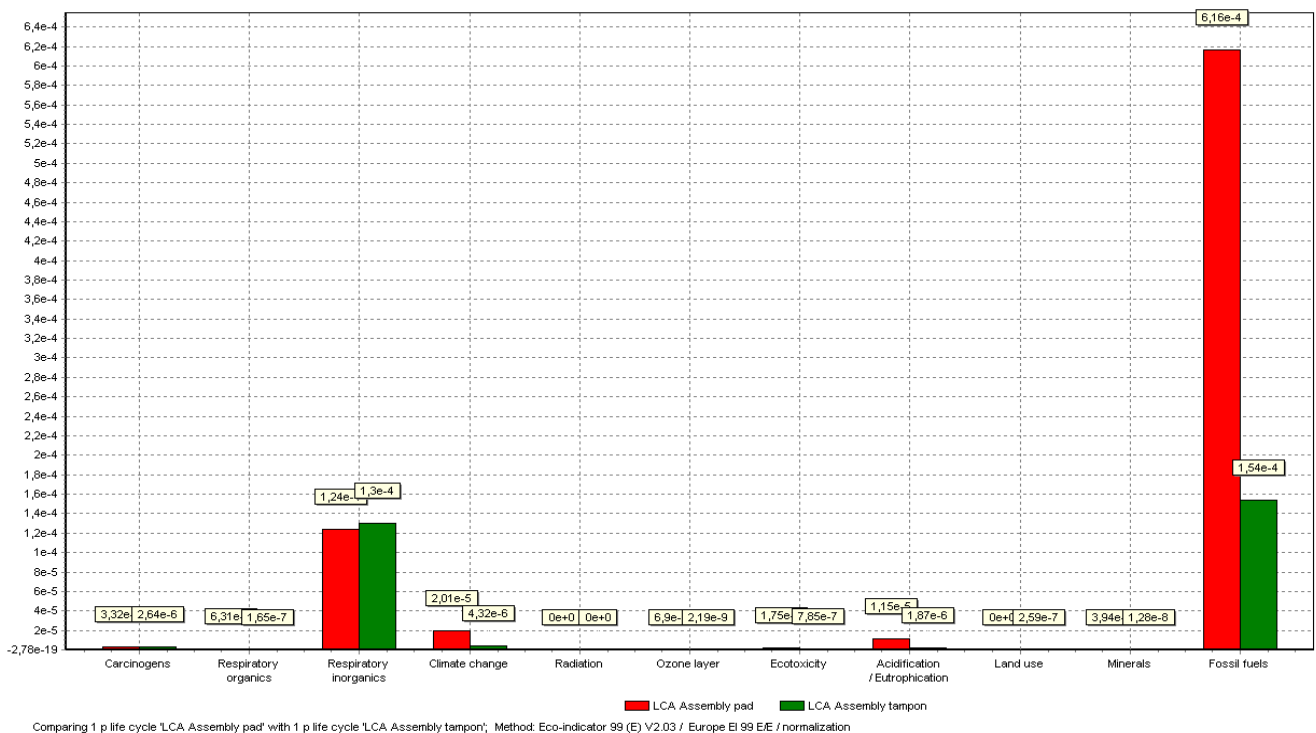
Characterization diagram (see figure 11) shows that pads have larger input into almost all types of environmental impacts. For carcinogenic impact the difference between two assemblies is the lowest, whereas for respiratory organics, climate change, ozone layer, ecotoxicity, acidification, minerals and fossil fuels use pads assembly exceeds tampons assembly for more than twice. There only two impacts which are mostly “fed” by tampons assembly: respiratory inorganics and land use, which is also explained by tampons “agricultural origin”.

**Figure 11: Pads vs. tampons comparative assemblies LCA – impact assessment, characterization**



Normalization diagram (figure 12) demonstrates that all impacts are insignificant compared to respiratory inorganics and fossil fuels.

**Figure 12: Pads vs. tampons comparative assemblies LCA – impact assessment, normalization**



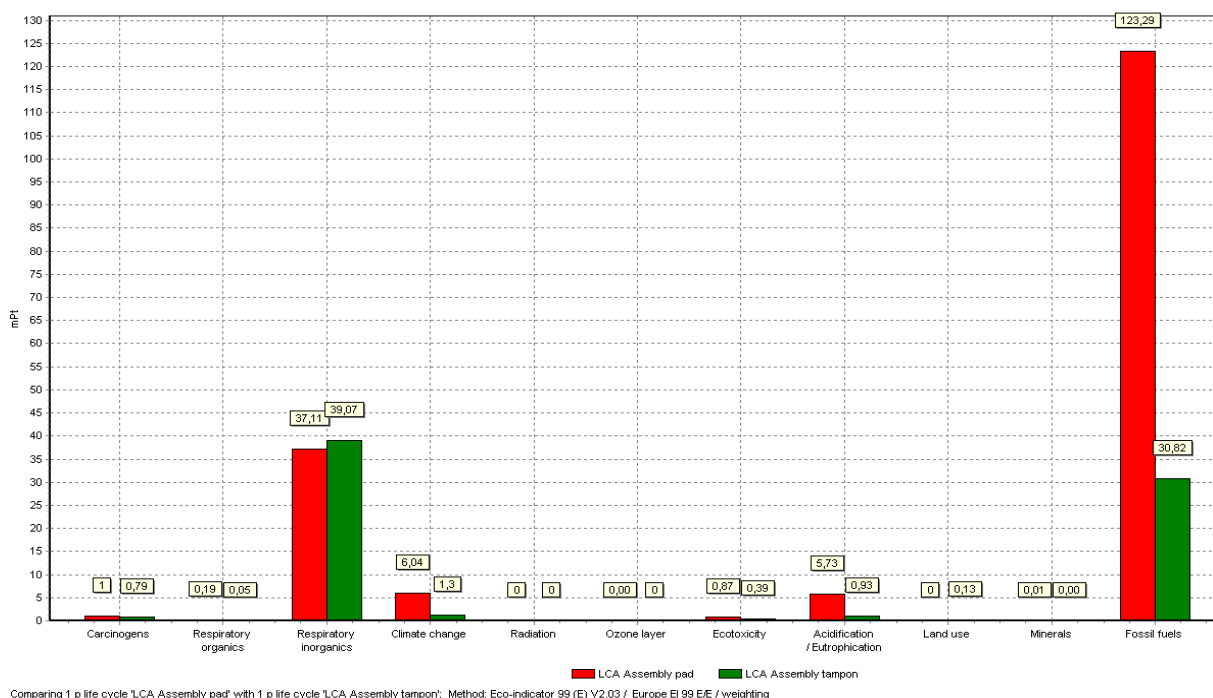
We would like to specify three the most important environmental impacts coming from pads and tampons assemblies.

### Human Health

In this part we would like to describe how negative effects caused by emissions from all product life cycle affect on the human health and his well-being.

As we can see from characterization diagram (figure 11), carcinogens bars are similar in pads as well as tampons case but after linking this result to weighing diagram (figure 13), it can be appraised that this impact does not play big role in whole influence. However, during our investigation and information collecting we happened to come up against huge problem of the tampon’s contamination with asbestos and dioxin which cause toxic shock syndrome. Obviously, we did not gain this kind of information from producers, and we could not enclose them to our assessments. We do not have any results referring to this information, but we will come back to this in discussion part because we considered this aspect essential for woman’s health.

**Figure 13: Pads vs. tampons comparative assemblies LCA – impact assessment, weighting**



The climate change and ozone layer depletion have also some contribution in overall impact of both products. These impacts are mainly caused by emissions during the mining, processing and production of polymers (such emissions as hydrocarbon, carbon dioxide and other greenhouse gases). The participation of this impact in tampon’s assembly is less noticeable because the amount of plastics in functional unit of this product is negligible.

Big parts in both pads and tampons assemblies present a problem of respiratory inorganic (35 mPt – pads, 38 mPt – tampons). Also basing on weighing diagram and comparing respiratory inorganic with others impacts we can notice that this problem is significant. The main emissions considered as respiratory inorganic are NO<sub>x</sub> and SO<sub>x</sub> that are released during LDPE production process. Also cotton cultivation is a source of NO<sub>x</sub> and SO<sub>x</sub> emissions mostly because of the agricultural equipment.

### Ecosystem Quality

Three main impacts make up this category - acidification/eutrophication, land use and ecotoxicity, which is helpful to assess ecosystem’s condition and its threats.

Acidification/eutrophication as a part of ecosystem quality category is caused mainly by SO<sub>2</sub> emission from polymers production and NO<sub>x</sub> and phosphorus emissions from cotton’s fertilization.

Acidification is caused by acid depositions from anthropogenic emissions of the pollutants. Sulphur dioxide and the nitrogen oxides are emitted by burning and processing fossil fuels used to polymers production and transport. Acid depositions have a negative impact on water, forests, and soil. Damage is also evident on man-made structures, such as limestone buildings and monuments.

Anthropogenic eutrophication is water pollution caused by excessive plant nutrients. Farmers add excessive amounts of plant nutrients (primarily phosphorus, nitrogen, and carbon) to streams and lakes in various ways. Runoff from agricultural fields during cotton production is one of the sources of these nutrients. The excessive growth, or so called "blooms", of algae promoted by nutrients release change water quality in lakes and rivers. These algal bloom leads to oxygen depletion and results in fish kills.

Land use – a main impact related to cotton cultivating. Agricultural operations sometimes involve activities that are harmful not only for the soil, but also for water supply, and biodiversity. The expansion of agriculture and use of pesticides results in hurt of the various species therefore the biodiversity in cotton fields is decreased. Also mono-cultivation leads to impoverishment of the soil. Cotton is a highly water intensive crop, requiring more than 20,000 liters of water to produce 1 kg of cotton. In addition, 73% of global cotton harvest comes from irrigated land [9]. Irrigation often results in rising water tables, water-logging, salinization, and water wastage.

### Resources

The fossil fuels depletion is by fare the most significant impact form the whole life cycle of our products. It is noticeable not only from the single score diagram (see figure 10) which collects all impacts in one bar and thanks to it is better in highlighting the particular impact's participation, but also from weighing diagram that stressed the real importance of the specific influence.

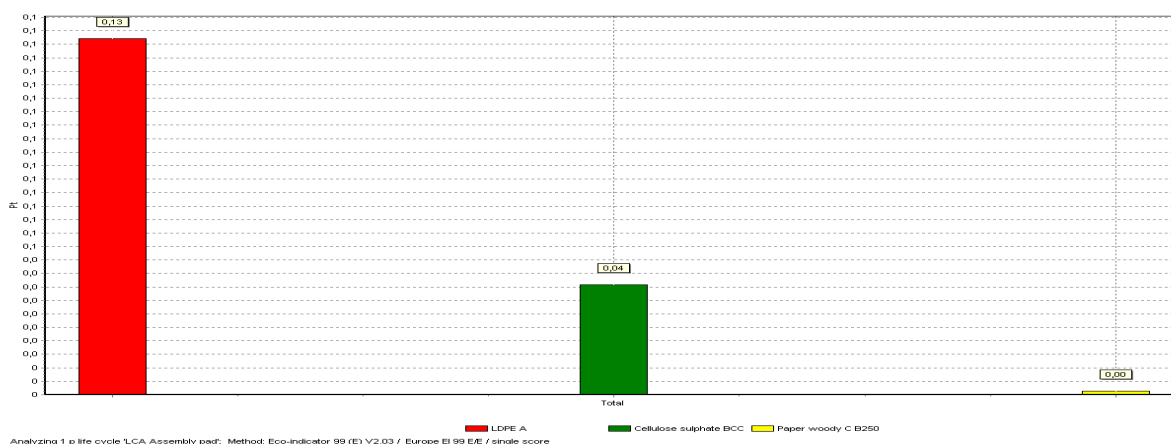
The most significant cause of resources use is manufacturing plastic in petrochemical factories. Fossil fuels provide both the power and the raw materials that transform crude oil into common plastics such as polystyrene, polyethylene and polypropylene. The sustainability of their production has increasingly been called into question. Known global reserves of oil are expected to run dry in approximately 80 years, natural gas in 70 years and coal in 700 years, but the economic impact of their depletion could hit much sooner [12]. It follows that the production such an indispensable for woman's hygiene product has tremendous effect on the fossil fuel reserve's reduction.

As we can notice the fossil fuels and mineral depletion plays the biggest role also in tampons assembly. This is connected with the cotton cultivating. Fertilizers, herbicides and pesticides are fossil fuel and chemical (mineral) products and when wastefully used diminish the storage of resources. The application of the motorized equipment, automated watering systems, distribution systems and tractors – all based on petrol, and all needing energy makes agribusiness huge environment's enemy.

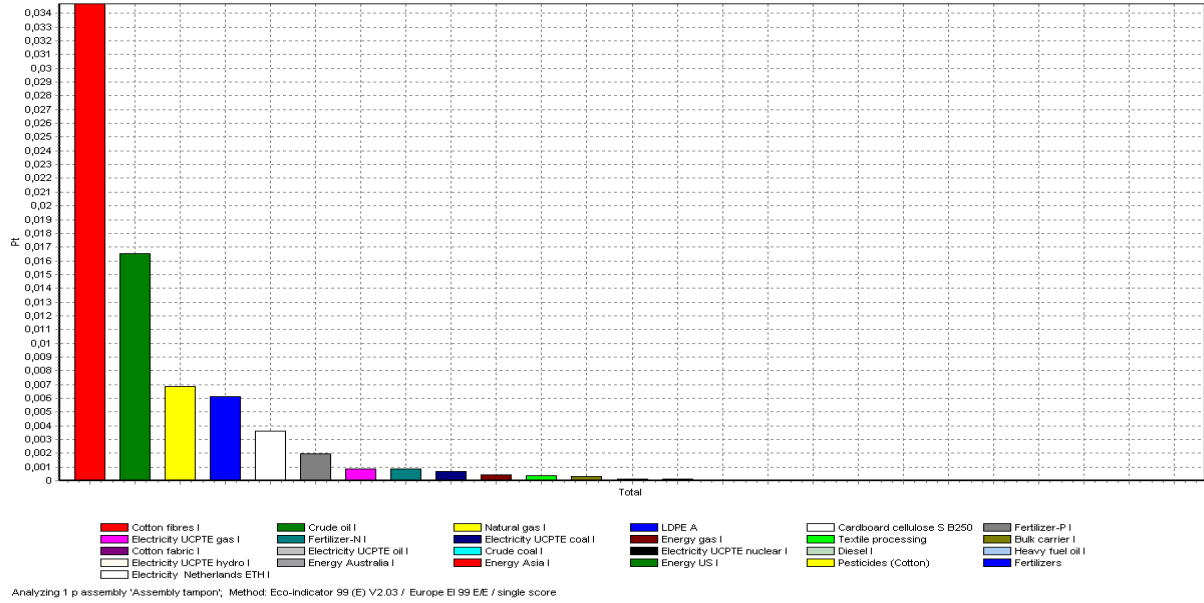
Another main source of fossil fuel consumption is transport of pads and tampons from the production place to the shop and further to the clients.

Figures 14 and 15 demonstrate inputs of assemblies' parts into total assembly impact. Again, it can be seen that LDPE makes the largest input into pads assembly impact, and cotton fiber – into tampons assembly impact.

**Figure 14: Pads assembly – process contribution, single score**



**Figure 15: Tampons assembly – process contribution, single score**



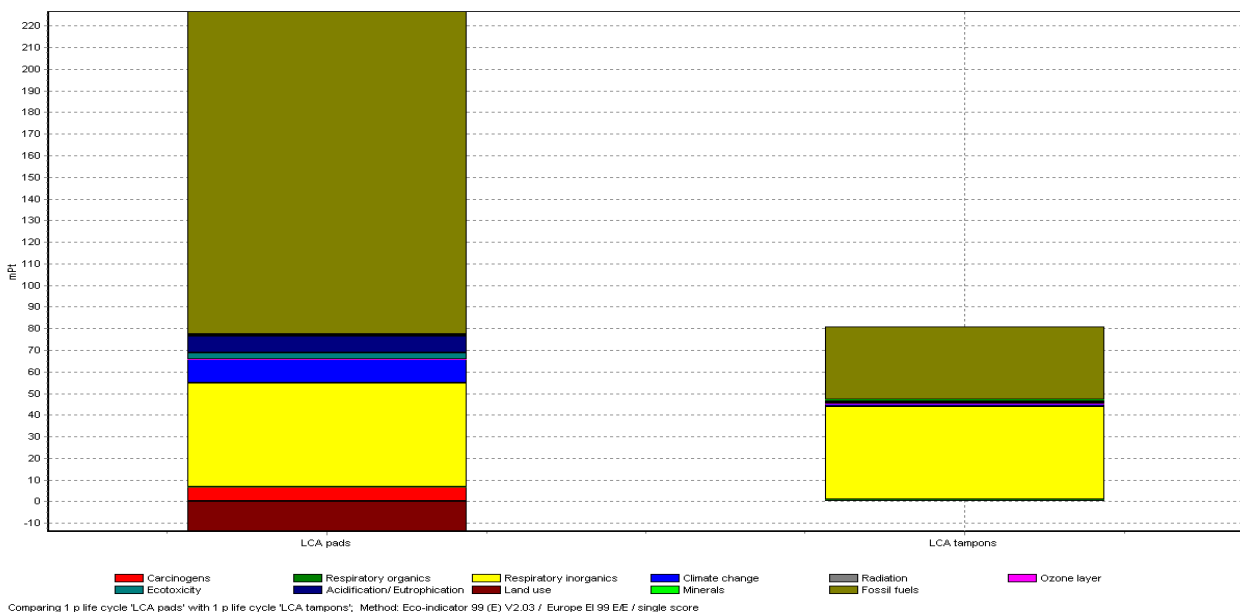
Different source libraries with correspondingly different degree of detail makes these two diagrams quite confusing perceived: it seems like tampons assembly is much better investigated due to more number of columns. In fact, this different level of detail appears when data comes from different sources. Still, we can clearly see inputs of different materials constituting assemblies.

### 3.3. Sanitary pads LCA versus tampons LCA

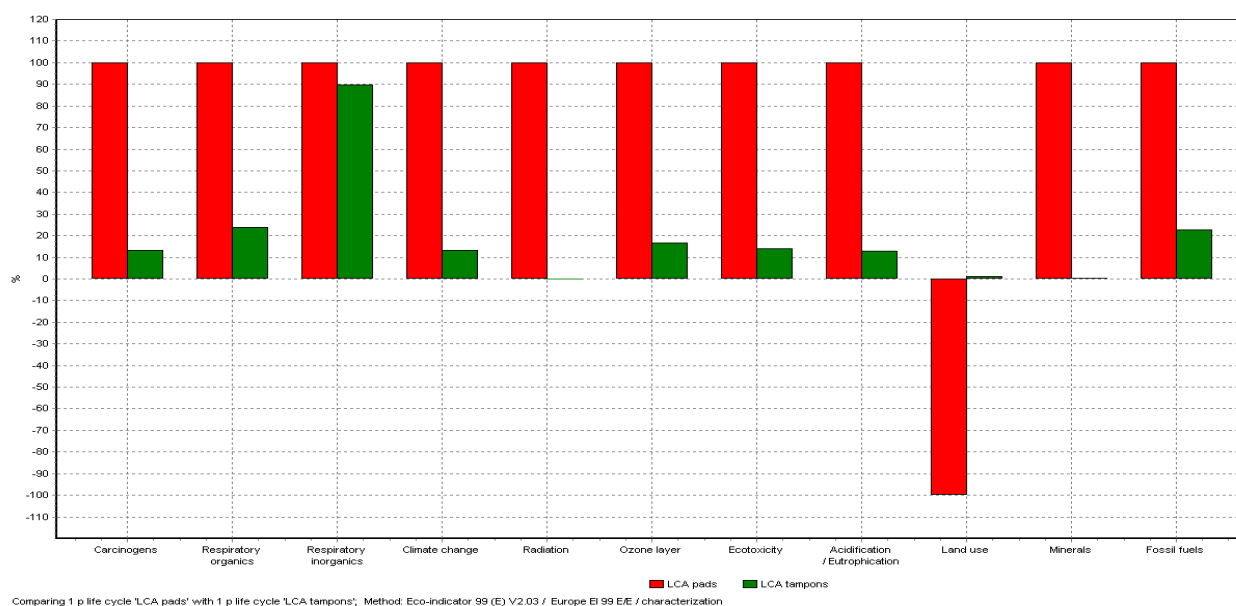
Lack on quantitative data on tampons production doesn't allow direct comparison of pads and tampons life cycles. We can only make some judgments according to available data.

Columns structure in single score diagram (see figure16) is almost the same as in assemblies comparison diagram (see figure 10). Characterization diagram (see figure 17) reveals some differences. Only respiratory inorganics columns are quite similar, into all other impacts (except land use) pads contribute significantly much more than tampons. Land use “negative” values have been already explained.

**Figure 16: Pads and tampons LCA in comparison – impact assessment, single score**



**Figure 157: Pads and tampons LCA in comparison – impact assessment, characterization**



These two diagrams can't be considered as direct comparison, they are based on different data: pads life cycle is comprehensive, and tampons life cycle lacks large amount of data. But these pictures allow us make assumptions on the values of impacts that can be added from tampons life cycle so that total environmental impact from tampons life cycle could exceed pads life cycle's impact. The data lacked include transportation of raw materials and production, energy and water consumption, emissions and effluents during tampon production. Estimation of these data inputs in the two last given diagrams is an interesting but rather speculative question. Perhaps, adding transportation can greatly change columns distribution, as cotton is not cultivated in Europe and should be therefore often exported for long distances. Emissions and effluents during tampons production are most probably not so significant (as it is mainly mechanical process), and it is quite difficult to assess energy consumption without specific data. If industrial wastes are recovered (which is quite possible although we don't have exact data) then land use column would be also lying under zero level.

## DISCUSSION

As mentioned in interpretation part, during our investigation and information gathering we came up against the problem concerning the toxicity of the tampon caused by the presence of dioxins and other harmful components. We weren't able to gain any kind of information confirming this from producers, but we consider this problem to be essential enough to raise it in discussion part in order to highlight this usually hidden issue.

Dioxins are known to cause cancer in animals, and probably cause cancer in people. People exposed to high levels of dioxins may be at risk for a damaged immune system, increased risk of pelvic inflammatory disease, and reduced fertility.

Until the late 1990's a chlorine bleaching process that produces dioxin was used during the production of cotton used in tampons.

While the dioxin hazard from bleaching has been reduced in recent years as a result of new bleaching methods, dioxin is still detected in tampons. Due to decades of pollution, dioxin can be found in the air, water, and ground; thus, trace amounts of dioxin may be present in the cotton. According to the results of studies conducted by tampon manufacturers dioxin levels in the rayon raw materials range from undetectable to 1 part in 3 trillion.

It might seem negligible; however, even trace amounts of dioxin are cause for concern because tampons come in contact with some of the most absorbent tissue in the body [13].

As soon as bleaching process plays no other functions but esthetical it should be abandoned or replaced by less harmful methods. Also the chemical components should be pointed out on the package to ensure information and increase the awareness of the consumer.

## CONCLUSIONS

**Life cycle assessment** is a powerful analytical instrument which allows evaluation of all environmental impacts connected with products whole life-cycle: starting from raw materials extraction and processing, following transportation of raw materials, production stage, transportation of product, usage stage, and waste utilization. Well-developed quantitative assessment methods provide result in the form of numbers and diagrams which can be interpreted differently. There are a lot of assumptions and subjective choices during the assessment process which often cause dissatisfaction with life cycle assessment approach. Anyway, one of its advantages is possibility to make well-grounded choice between two or more product alternatives based on environmental impacts they make.

In our case, analysis of **sanitary pads life cycle** reveals that crucial process in the whole life cycle is LDPE processing. Even though cellulose constitutes more weight percent of a pad, it doesn't have so profound environmental impacts. It is due to high energy consumption of LDPE production and using oil as a raw material which is very valuable as an energy source. That is why the main impact from pads life cycle is fossil fuels use. Forestry and cellulose processing is much more environmentally friendly than plastics production. Most of the impacts come from raw materials processing and pads production; transportation also makes its input but not so large. Recovery of production wastes makes positive impact into environment saving land resources which otherwise could be used for forestry and wastes landfilling.

**Comparing assemblies**, absolute numbers (figure 10) show that tampons are twice as more environmentally friendly as sanitary pads. It is easily explained by the most significant materials constituting pads and tampons assemblies: for sanitary pads it is polyethylene, and for tampons it is cotton wool. Principal differences lie in processing stages of these two materials, causing totally different environmental impacts.

Pads life cycle is connected with mining, processing and production of LDPE which results in climate change and ozone layer depletion from emissions, and fossil fuels depletion. Acidification is also the result of sulfur and nitrogen oxides emissions.

Tampons don't contain so many LDPE that it could make significant effects. The most input is made by agricultural processes of cotton cultivation: especially fertilizing, washing etc. The main environmental impact is respiratory inorganics. Acidification and eutrophication caused by tampons production come from over- fertilizing.

Thus, respiratory inorganics and land use are the only two impacts that are influenced more by tampons than by sanitary pads. For all other impacts pads input exceeds tampons input significantly.

We faced different **problems** during our investigations. First, and the most important, was the lack of quantitative data. Environmental reports sometimes provide perfect and detailed data on some environmental aspects but pure – on others. Combined data for different types of products within one company forced us search for mills locations and products made on these particular mills. Environmental information from some mills was provided, so we solved this problem for pads production, but in any case, comprehensive, detailed and relevant information remains the greatest challenge when doing life cycle assessment. It also refers to data from databases and libraries, which are often of different levels of detail which is quite confusing. Comprehensive databases could be very helpful for analyst.

So, if we are supposed to give an environmentally-based **advice to women** who are going to make their choice – sanitary pads or tampons – conducted analysis is a good prompt but should not be considered as the only background. From assemblies comparison tampons is definitely better than pads, but comprehensive life cycle assessment can show results that will differ. There is a large room left for assumptions on the inputs of cotton transportation and energy consumption during tampons production stage.

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