

Material substitution and weight reduction as steps towards a sustainable disposable diaper

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Abstract Increasing market demands for 'sustainable products' has in the development of disposable diapers resulted in a focus on material substitution and weight reduction. In this study we have compared the strategic potential of these two approaches for development of the absorbing core of the product. The study indicates that regardless what strategy a company selects for reducing a products socio-ecological impact, both society and environment would benefit from a stronger focus on the long term goal of a sustainably product, instead of the milestones.

1 Introduction

Due to increasing human population, high consumption and un-sustainable management of products and services, we are now exceeding sustainable use of natural resources. In combination with impacts from e.g. ecosystem displacement and pollution of air, water and soil, this has resulted in a decline, on a global scale, of the potential of Earth's ecosystems to sustain civilization [1-3]. One way to reduce society's socio-ecological impacts is to reduce impacts caused by consumption of products. Strategies for reduction of products' socio-ecological impacts include developing new ways of fulfilling the function provided by the product, reducing the use of resources through various means of dematerialization, substitution of such materials that are difficult and expensive to manage in a sustainable way, and through increasing material and energy recycling.

The use of disposable diapers is significant, and 3-15 % (w/w) of the municipal solid waste has been calculated to originate from disposable diapers [4-5]. In addition, the use of incontinence diapers is expected to increase with the increasing number of old people [6]. The waste management of diapers is today mainly through incineration or landfill.

Producers, industry associations and organizations developing eco-labelling and procurement criteria use life cycle assessment (LCA) to measure the environmental impact of diapers. According to the sustainability report from the international association serving the nonwovens and related industries, Edana [5], material production and waste treatment are the two dominant life cycle phases behind the causes of global warming impact from diapers.

A diaper is generally built up by a back sheet of petroleum based Polypropylene (PP), 10 % (w/w); an absorbent core of Fluff Pulp, 30-60 % (w/w) and petroleum based Polyacrylate, so called SAP - Super Absorbent Polymers, 12-30 % (w/w); a top sheet made of Polyethylene (PE), 10 % (w/w) and other petroleum based materials such as tape, elastics and glues, 6 % (w/w) [5]. Consequently, non-renewable materials make up 40-60 % of a diaper.

During the past 20 years, the typical disposable diaper has developed into a thinner, drier and more comfortable product to wear, a product with reduced weight and with an improved function [22]. This has mainly been achieved through increased use of SAP which has high absorbency. Drivers in this development are, among others, criteria for eco-labelling and green procurement [5,7,8].

According to green procurement and eco-labelling organizations, future criteria for diapers are suggested to focus on reduction of the amount of non renewable material in the product on weight reduction, and on biodegradability of products [7,8]. The first steps in order to develop the product in accordance with these potential criteria is suggested to be one of the two following approaches; i) weight reduction through increased use of SAP in the product or ii) material substitution through making a new super absorbent from wood by utilizing the wood fiber properties[9]. However, to develop a substitute material in a product can be an expensive and time consuming process. Therefore producers want to ensure that the planned change will lead to a more sustainable product, give a return on investments, and that it will contribute to long term sustainable management of the product.

This takes us to the research question of the present study:

How can weight reduction compared to material substitution contribute to the long term development of a sustainably managed diaper?

2 Method

We have assessed the potential to contribute to a strategic movement towards a long term sustainable management of a diaper of two different approaches; i) weight reduction through increased use of SAP in the product and ii) material substitution through making a new super absorbent from wood by utilizing the wood fibers properties.

The assessment considers a full product lifecycle, where the diaper is incinerated as end of life treatment. However, production capital (e.g. construction of production facilities, roads or waste treatment facilities) will not be considered. Data for the assessment is collected from literature.

The assessment was performed using a generic framework for strategic sustainable development (FSSD) [11-15] . The FSSD is a five level framework for strategic planning towards a sustainability objective. The framework encourages a description of the system thorough enough (level 1), to be able to arrive at a robust definition of sustainability objective of e.g. a plan/project/organization or protocol (level 2), which is a prerequisite for making use of strategic guidelines (level 3) when actions (level 4) and support tools for monitoring, coordination and decision-making (level 5) are selected.

A clear definition of the desired outcome – the sustainability objective (level 2) is the key in any planning effort. For complex systems, e.g. the life cycle of disposable diapers within society within the biosphere; the objective is preferably defined by overarching principles that have to be met in a sustainable society. Only after success is clearly defined, can strategic guidelines (level 3) be of support for the selection of actions (level 4) to systematically approach the defined success (level 2).

The system analyzed in this study is 'the life cycle of disposable diapers'. The sustainability objective was defined as long term sustainable life cycle of diapers where sustainability was defined by the four sustainability principles (SP1-4) of the FSSD:

In a sustainable society, nature is not subject to increasing...

SP1 - concentrations of substances extracted from the Earth's crust,

SP2 - concentrations of substances produced by society,

SP3 - degradation by physical mean.

And in that society...

SP4 - people are not subject to conditions that systematically undermine their capacity to meet their needs.

It is noteworthy that the principles are designed as constraints for sustainability in the whole biosphere. For the individual organization or topic, in this case the lifecycle of disposable diapers, the context is given by asking if it contributes to violations of the sustainability principles.

The strategic guidelines, from which we assessed the different approaches, were:

- Will the approach lead in a direction towards success?
- Does the approach constitute flexible platforms for further development towards success? It is important not to "lock on target" prematurely by having overly rigid ideas what sustainability will look like.
- Will the approach give sufficient return on investment allowing for continuous improvements towards the goal?

3 A sustainably managed product

3.1 Demands on a sustainably managed diaper

A sustainably managed diaper must not, during its lifecycle, contribute to violations of any of the SP's - to avoid solving one problem by introducing a new. For a sustainably managed diaper that is incinerated after use, this means that its function should be fulfilled, it should absorb and retain liquids in an excellent and resource efficient manner (SP4). Furthermore, it should be produced by renewable resources that are extracted from sustainably managed ecosystems (SP3), and it should not emit any persistent substances foreign to nature (SP2) or substances possibly harmful to humans or ecosystems during its lifecycle (SP1 & SP2). Finally, all processes in the products lifecycle should be guided by respect for human rights (SP4).

3.2 Gaps for existing products in relation to a sustainably managed diaper

The gaps for existing products in relation to the above outline of a sustainably managed diaper are discussed in the following section.

SP1 Diapers consist of 40-60% plastics produced from limited non renewable resources of petroleum. The incinerated plastics will be emitted as carbon dioxide and contribute to global warming. The production processes and transports are energy demanding and will, if non renewable energy sources are used, contribute to global warming.

SP2 Substances will increase in concentration due to either that they are persistent (often because they are foreign to nature), as for dioxins from incineration or that the anthropogenic flows are relatively large in comparison to natural flows e.g. NO_x from transport emissions and/or incineration. Use of auxiliary chemicals (chemicals used in production), and stabilizing agents and other additives in the plastics are known to contribute to emissions of substances that risk increasing concentrations in nature. Another issue, particularly associated with use of incontinence diapers for elderly people, is contamination by drug residues. Most of these drug residues will transform into naturally occurring substances during incineration, however there might be residues left in the ashes [16].

SP3 Wood harvesting for the pulp might lead to degradation of nature, if the forest is not managed in a sustainable way. Ashes from incineration of waste are put on landfills and will cause displacement and degradation of nature.

SP4 Diapers can have a positive impact on people's lives by fulfilling their function in a way that let the user be more active. In order not to contribute to violations of people's possibilities to fulfill their needs, it is of importance that all processes are guided by respect to human rights and that resources are used in an efficient way to make sure available resources are enough to fulfill different needs in a global perspective.

3.3 Approaches in relation to the sustainability objective

The previous section reveals that there are significant gaps between today's diaper and a sustainably managed diaper. How will then the two approaches: i) weight reduction through increased use of SAP in the product and ii) material substitution through making a new super absorbent from wood by utilizing the wood fibers' properties contribute to fill this gap?

3.3.1 Weight reduction through increased use of SAP in the product

SAPs are known to have excellent liquid absorption properties. Increasing the amount of SAP in the product will therefore give a possibility to reduce the amount of fluff, thus enabling a reduction of the product's total weight.

SAPs are today not produced from renewable resources but research is conducted within this area [5,16,17-20]. The SAP is known to be problematic in landfills due to that it is not biodegradable (SP2) [4,9], this product is therefore not suited for alternative waste treatment systems like landfill or composting.

3.3.2 Material substitution through replacing SAP with absorbents made from wood

One environmental implications associated with the use of SAP produced from petrochemicals, is that the substances will, through incineration, be transformed into carbon dioxide (SP1). Material substitution by replacing the SAP with super absorbents made from wood fiber, will, increase the amount of material produced from renewable resources in the diaper. Research is conducted for making super absorbents from wood [9].

3.4 Strategic potential for the assessed approaches

When selecting what approach that will best contribute to a movement towards a sustainably managed product, there are three important strategic guidelines to evaluate them from. 1. Will the approach lead in the right direction? 2. Will the

approach build flexible platforms that make continuous progress towards success possible? 3. Will the approach give return on investment that allows for continuous improvements?

Both approaches have the same possibility to fulfill the required function, to only use renewable resources produced in sustainably managed ecosystems and ensure that all processes in the lifecycle are in line with criteria for social sustainability.

If today's SAP can be produced from renewable resources and a wood fiber super absorbent can be produced, both approaches have the same possibility to reduce the amount of non renewable material in the product.

If the product will be incinerated after use, both approaches have the same possibility to prevent emissions of substances possibly harmful to the environment. However, absorbents made from wood might be better suited for other waste treatment solutions, e.g. biological treatment, since it relies on a biological structure [4].

In the long term, the best diaper will be the one where the line of approaches will be performed in concert with market requirements and technical and economic feasibility. The possible return on investment is partly dependent on customer requirements. Today, many customers rely on eco-labelling and green procurement criteria to be able to consider sustainability aspects for a product. However, since both eco-labelling and green procurement criteria are focused on which of the alternatives that has the least weight, green house impact or contains the highest amount of material originally from renewable resources[7,8], there is a lack of a long term perspective focused on the 'sustainably managed product'. If the companies or the trade organization instead could move their focus towards the long term goal of a sustainable product, and communicate this long term goal as well as their strategy to approach it, it would be a win-win situation for the environment, the society and the companies.

We therefore recommend that the industry association, except demands regarding relevant laws and regulations, also focus on: 1) what are the gaps towards a sustainably managed product, 2) how could a long term strategy towards a sustainably managed product be built and 3) communication with customers as well as eco-labelling and green procurement organizations to build a movement towards a common goal.

4 Summary and conclusion

Today's diapers need to develop to fill the gap towards a sustainably manageable product. This development would benefit from a long term perspective focused on the sustainability objective instead of competing in every single step of the development, e.g. regarding fulfillment of eco-labelling or green procurement criteria focused on what product that has the lowest weight or the highest percentage content of substances originally from renewable resources at a specific time - it is more important to win the race than to win the sprint prizes in the beginning of a long race.

The development of a 'sustainably managed diaper' is dependent on many different aspects, e.g. resource availability, material development and customer demands. Regardless what strategy a company selects for improvement of their product, it is essential, in order to get return on their investments, that they communicate what they are doing and put this in relation to their goal. That would reduce the risk of customers losing trust in the company's socio-ecological ambitions, as well as allow for the customer and society to support a long term strategy towards a sustainable product.

Our study has discussed sustainability from many dimensions: sustainability for the whole biosphere (second level of FSSD), strategically/economically stepwise approaches while ensuring a sufficient return of investment, how easy it is to recycle materials, impacts at the site of sourcing and functionality - allowing the strategic approach to also improve or at least not deteriorate the functionality.

This inherently means that there are many criteria for the evaluation of the sustainability of materials, distributed along different axes. What we would need today is databases for materials, where such criteria are evaluated separately. In each choice of different alternatives, during a product development cycle, the adequate criteria could be chosen. Data bases are generally not designed to allow this. The current design of material data-bases either have too few criteria, and/or are aggregating the criteria into "stories" that does not allow for a transparent display of the essential components for strategic sustainability approaches. In forthcoming studies, we are going to explore the feasibility of designing such data-bases.

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